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The maps and diagrams in this volume were drawn by Messrs. J. Ngai, Poon Puay-kee and Wee Hong Seene.

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SOME OBSERVATIONS ON KARST DEVELOPMENT IN THE MALAY ARCHIPELAGO

By H. Th. VERSTAPPEN

INTRODUCTION

THE DEVELOPMENT of limestone landscapes in the humid tropics is no new topic in the field of climatic geomorphology. The almost impassable terrains covered with countless conical or spherical hills, unknown in the moderate climates, aroused the curiosity of many investigators. The famous karst area of the Sewu Mountains in Java played a role of special importance in the advancement of knowledge in this matter, as it was the subject of several classical studies. Grund developed his well known 'karst cycle', with sinkholes as the initial stage and subsequent uvala, cockpit and hum stages, on the strength of Danes' investigations in the Sewu Mountains.[1] The positive terrain forms, that is the hills, according to Grund are formed only during the later stages of karst development. Lehmann, in studying the land forms of the Sewu Mountains, became convinced that the conical karst hills are typical for the humid tropics and originate as such at the very beginning of the landscape development.[2] He thus fully rejects Grund's karst cycle hypothesis, in which karst features formed in different climates are considered as subsequent stages of a general development.

The fact that numerous hills are formed instead of the 'normal' scattered sinkholes, points to a much quicker rate of solution of lime in the humid tropics than in the moderate climates. This seems at first sight incomprehensible, as the solubility of lime depends mainly on the carbon dioxide content of the water according to the formula:

$$CaCO_3 + H_2O + CO_2 \rightleftarrows Ca(HCO_3)_2$$

The cooler the water, the more carbon dioxide can be solved and thus, theoretically, a quicker rate of solution of lime would be expected in the cooler climates, which is not the case.[3] The explanation of this fact is offered by Bögli, who made a detailed study of the matter and proved that the speed of the chemical reactions involved in the tropics is much higher (up to 400 per cent) than that of alpine and arctic climates.[4] Lehmann furthermore stresses the importance of 'biological' carbon dioxide produced by the macro- and microvegetation of the tropical limestone slopes.[5]

1. A. Grund, 'Der geographische Zyklus im Karst', *Zeitschrift d. Gesellsch. f. Erdkunde*, Berlin, 1914, pp. 621-40; and J. V. Danes, 'Die Karstphänomene im Goenoeng Sewoe auf Java', *Tijdschr. Kon. Nederlandsch Aardrijkskundig Genootsch.*, Vol. XXVII, 1910, pp. 247-60.
2. H. Lehmann, 'Morphologische Studien auf Java', *Geographische Abhandlungen*, III^{e} Reihe, 9, 1936.
3. H. Lehmann and others, 'Das Karstphänomen in den verschiedenen Klimazonen', *Erdkunde*, Vol. VIII, 1954, pp. 112-39.
4. H. Lehmann and others, 'Report of the Commission on Karstphenomena', *XVIIIth International Geographical Congress*, Rio de Janeiro, 1956.
5. H. Lehmann and others, 'Karstmorphologische, geologische und botanische Studien in der Sierra de los Organos auf Cuba', *Erdkunde*, Vol. X, 1956, pp. 185-204.

The chemical observations carried out in the last few years on karst water in several tropical and temperate regions of the world point to a higher content of aggressive carbon dioxide in the humid tropics. This fact, together with the abundant rainfall, accounts for the quicker solution of lime in the tropics, as evidenced by field observations. The lack of cold periods during the pleistocene is also mentioned as a factor in this connection. In the moderate climates the ice ages had a tremendous influence on weathering in general, and also on karst development, whereas in the tropics the changes were only of minor importance.

CHEMICAL ANALYSES OF KARST WATER IN THE SEWU MOUNTAINS OF JAVA

A few measurements were carried out in the Punung area, situated to the north-west of the town of Patjitan, in 1955 and 1956. Three localities where reliable results could be expected were chosen as sample spots, namely, the Tabuan Cave and the Songkuren and Telagadukur Springs. The samples collected in the Tabuan Cave represent water slowly percolating through fissures in the limestone, whereas at the other two sample spots large amounts of water emerge at the foot of the limestone hills. The following results were obtained :—

Location	Lime Content	Aggressive CO_2
Tabuan Cave	70 mg/1	0.0
Songkuren Spring	131 mg/1	6.6
Telagadukur Spring	149 mg/1	2.2

The percolating water of the Tabuan Cave has a considerably lower lime content than the water emerging at the springs, and no aggressive carbon dioxide is found in the cave.

The lime contents observed by the author are similar to those mentioned by Lehmann of comparable localities in Cuba.[1] They do not differ greatly from European values either. The higher lime content of karst water in the humid tropics occurs especially in the beginning of the solution process, that is, in water superficially running down lapiés, as is pointed out by Lehmann.[2] The latter values account for the fact that tropical limestone areas quickly reach old age and have intense lapiés development (Plate 4). Completely different land forms, however, comprising countless rather regularly distributed conical hills instead of 'normal' scattered sinkholes, can hardly be explained in this way. One would rather expect that those areas in the tropics went through some universal karst cycle, if any, quicker than in other climates. If typical conical hills are present, however, they are developed right in the beginning of the solution process. A climatological explanation alone thus seems inadequate to explain all the phenomena observed. Other, lithological, factors apparently play an important role.

1. Lehmann and others, 'Report of the Commission on Karstphenomena'.
2. Ibid.

Plate 1

Pseudo conical karst hills carved in Tertiary conglomerates near Pajakumbuh, Central Sumatra.

Plate 2

The Gedeh River, Sewu Mountains, Java, disappearing at the foot of a small limestone hill near Tabuan.

Plate 3

The huge karst canyon and natural bridge of the deserted underground course of the Warok River, Central New Guinea. Note the track over the bridge connecting the villages on either side of the canyon.

Plate 4

Lapiés developed on the slopes of a conical karst hill in the Sewu Mountains, Java. Their rounded-off shapes and intricate pattern are characteristic of inland limestone areas in the humid tropics.

Plate 5

Landscape of limestone hills and small tuff plains near Tabuan, Sewu Mountains, Java. Several conical hills are formed in every bioherm.

Plate 6

Karst canyon of the Matjao River, near Watampone, South-west Celebes, formed in a conical karst landscape. Scale 1 : 40,000.

Plate 7

The Gedeh River, where it reappears from the limestone hill of Plate 2. The river traverses a small tuff plain and disappears at the foot of the limestone hills in the background.

MALAYSIAN KARST FEATURES AND THEIR DIVERSIFIED CAUSES

The karst literature of the Malay Archipelago mainly deals with the limestone regions of southern Java. Besides the above mentioned studies of Danes[1] and Lehmann,[2] publications on this area exist from Hol,[3] van Valkenburg and White,[4] Bothé,[5] Escher,[6] Pannekoek,[7] and Sartono.[8] The last mentioned publication is an interesting study on the Punung area of the Sewu Mountains. The literature about the karst areas of the other islands is only scanty. Two short articles inform us about an underground river on the island of Halmahera,[9] whereas a comparable though much larger example from Central New Guinea is described by Montagne.[10] Wiszmann mentions the occurrence of tower karst in Malaya and Central Sumatra[11] and Verstappen describes karst features of the reef caps of the island of Muna (South-east Celebes) and of Key Minor (Moluccas).[12] A recent publication by Sunartadirdja and Lehmann deals with South-west Celebes.[13] The only more general article, though mainly dealing with a karst area of New Guinea, is from Pannekoek.[14]

The scarcity of the data available at present precludes a survey of any completeness of the existing karst features. Only a few interesting aspects therefore will be discussed here. Limestone areas, with their thin soils, do not generally offer a very favourable environment for human activities and this is especially true for tropical karst regions. In the Stone Age, however, the situation was different. Good protection was found in the abris and grottoes of the limestone areas where, furthermore, silicified limestone offered the necessary material for stone axes and other implements. Occasional small plains bordered by limestone hills, such as collapsed underground river courses, polje, and so forth, are the most likely sites of prehistoric settlements. The centres of civilisation were only shifted to the fertile Javanese lowlands after men had mastered the techniques of irrigation and had developed a higher agricultural standard.

1. Danes, op. cit.
2. Lehmann, 'Morphologische Studien auf Java'.
3. J.B.L. Hol, 'Danes' verhandeling over den Goenoeng Sewoe', *Tijdschr. Kon. Nederlandsch Aardrijkskundig Genootsch.,* Vol. XXXV, 1918, pp. 414-21.
4. S. van Valkenburg and I.Th. White, 'Enkele aanteekeningen omtrent het Zuidergebergte (G. Kidoel)', *Jaarverslag Topografische Dienst Batavia,* Vol. XIX, 1923, pp. 127-40.
5. A. Ch. D. Bothé, 'Djiwo hills and southern range', Excursion Guide C 1, *Fourth Pacific Science Congress,* Bandung, 1929.
6. B. G. Escher, 'De Goenoeng Sewoe en het probleem van de Karst in de Tropen', *Handelingen XXIII^{e} Natuur-Geneeskundig Congress,* 1931, pp. 259-61.
7. A. J. Pannekoek, 'De geomorphologie van het West-Progo gebergte', *Jaarverslag Topografische Dienst Batavia,* Vol. XXXIV, 1938, pp. 109-38.
8. Sartono, *The Stratification of the eastern end of East Java,* Bandung, 1958, (Thesis).
9. H.O.M. Bensemann, 'De grot Sagea op Halmahera', *Jaarverslag Topografische Dienst Batavia,* Vol. XX, 1924, pp. 70-1; and B.C.D. Drejer, 'De grot van Sagea (Halmahera)', *Tijdschr. Kon. Nederlandsch Aardrijkskundig Genootsch.,* Vol. XLII, 1925, pp. 253-6.
10. D. G. Montagne, 'Geologie en topografisch beeld, II', *Tijdschr. Kon. Nederlandsch Aardrijkskundig Genootsch.,* Vol. LXVI, 1949, pp. 468-72.
11. Lehmann and others, 'Das Karstphänomen in den verschiedenen Klimazonen'.
12. H. Th. Verstappen, 'Een en ander over het rifpantser van het eiland Muna, SE Celebes', *Tijdschr. Kon. Nederlandsch Aardrijkskundig Genootsch.,* Vol. LXXIV, 1957, pp. 441-9; and H. Th. Verstappen, 'A contribution to the geomorphology of the Moluccas, II, The reef cap of Key Minor in relation to the landforms of the Key and Tanimbar archipelagoes', *Publication Geographical Institute Djakarta,* 9, 1960.
13. M. A. Sunartadirdja and H. Lehmann, 'Der tropische Karst von Maros und Nord-Bone in SW. Celebes (Sulawesi)', *Ztschr. of Geom.,* Suppl. 2, 1960, p.p. 49-65.
14. A. J. Pannekoek, 'Eenige karstterreinen in Nederlandsch-Indië', *Nederlandsch Indische Geografische Mededeelingen,* Vol. 1, 1941, pp. 16-19.

An important question is the geographical distribution of tropical karst phenomena in the archipelago, as limited by climatological factors. Temperature as a limiting factor plays a role in the Central Mountains of New Guinea. The author observed that where limestone beds with typical conical karst development reach an altitude of 1500 to 2000 metres above sea level they lose their tropical characteristics and only show sinkhole formation. The upper limit of the conical karst landscape cannot be defined more precisely, because it differs substantially from the one limestone to the other. In the highest parts of the mountains only coral limestone still shows conical hills. Local differences in annual precipitation and also in temperature increase the intermingling of both groups of karst features. Not all karst regions can be classified in the two types just mentioned. Large areas are of an a-typical or transitional nature where both positive and negative terrain forms occur. This type, which might be labelled 'labyrinth karst', is characterized by an irregular and wild karstification. Some of these virtually impassable areas occur even at low altitudes. Obviously the solution of lime goes on quickly.

The precipitation limit of conical karst landscapes is reached in the Lesser Sunda Islands and the South-east Moluccas, where it can be observed at several localities that no tropical karst is developed in pure limestones. An exact value of prohibitive minimum precipitation is hard to give due to complicating factors, in much the same way as has just been explained for the temperature limit. The length of the dry season plays a role together with the annual precipitation and, of course, the lithology of the limestones concerned. A precipitation of 1500 mm, combined with a prolonged dry season, can be mentioned as an approximate limit for conical karst formation.[1] This figure will not hold true for every limestone, however, and transitional zones will also be present. The remainder and larger part of the Malay Archipelago is included in the belt of 'conical karst', provided that limestone of suitable lithological composition is present.

Many factors apparently influence the tropical karst development. Lapiés, for instance, develop at a very high rate in the humid tropics. The important role of biological carbon dioxide in this connection appears especially clear from the water analyses on lapiés in the island of Cuba.[2] Another result of the dense vegetation of most tropical limestone areas is the high content of humic acid in the karst water. Active lapiés formation therefore goes on under the thick soil cover. These facts explain the intricate lapiés pattern usually present, of which Plate 4, a photograph of a deforested slope in the Sewu Mountains, is a good example. The difference between the sharp pointed lapiés along tropical shores and the more rounded-off shapes of the inland lapiés is most likely to be explained by the solvent action of the spray from ocean surf.

Relief is another factor in the development of limestone landscapes, coming next to lithology, climate and vegetation. It was observed by the author that in the Pajakumbuh area of Central Sumatra, much higher and steeper conical hills are formed on sloping limestone beds than on the more or less horizontal parts (Fig. 1). On extremely steep slopes, however, no conical hills can be formed at all. Huge and deep crevasses, lapiés, take their place in such cases. The uplands then are characterized by conical karst hills whereas the surrounding steep slopes only show unimportant karst features.

1. F. H. Schmidt and J. H. A. Ferguson, 'Rainfall types based on wet and dry period ratios for Indonesia with western New Guinea', *Verhandelingen Djawatan Meteorologi dan Geofisik*, Djakarta, 1952.

2. Lehmann and others, 'Report of the Commission on Karstphenomena'.

Typical tower karst with its perpendicular hill sides is developed by lateral solution at the karst water level where limestone occurs in the valley floors. Tower karst is therefore to be considered as conical karst formed under special hydrological circumstances. The classical tower karst area of the world is located in South-east China and is described by Wiszmann,[1] who also invented the name 'Turmkarst'.

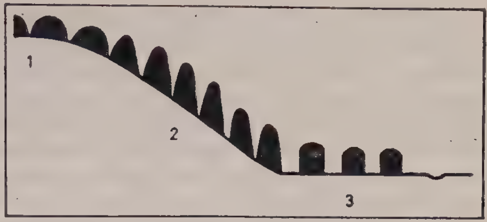

Fig. 1. Schematic section through limestone landscape near Pajakumbuh, Central Sumatra. Normal conical karst hills (1) are developed on the high land; steep and high hills (2) are found on the valley sides; and tower karst hills (3) with perpendicular sides are formed in the broad river plain.

Karst border plains are usually explained as the result of increased solution at the level of the ground water, in the same way as has just been described for tower karst. The formation of many karst border plains is a complex problem, however. Abrasion and marine solution played a role in South-east Celebes, whereas in southern Java their genesis is largely influenced by faulting phenomena. The karst border plains occurring in the Miocene limestone areas of New Guinea's 'Birdshead' are so irregular in outline that they can best be considered as representing the limit of the original coral growth, accentuated by subsequent solution.

Interesting observations were made on the karst development of raised coral reefs of Pleistocene age.[2] It was observed that the conical hills in such terrain are much better developed than in other limestones. Even the lowest and youngest raised reef edges already show initial conical hills. They are aligned according to the reef edges and thus in these areas the former coastlines can be reconstructed even if the reef edges themselves are no longer clearly discernable. Only in the raised lagoons, where less pure limestone is found, are sinkholes formed. The joints that often play a role in their genesis can be traced on air photographs. A special type of sinkhole, usually very large and with perpendicular sides, is found in the purest raised reef limestones. This phenomenon is confined to cavernous parts, or pools of the original living reef. In a few instances the influence of faults could be demonstrated, but these are not thought essential in general. Their origin dates back from before the uplift, and subsequent solution is of subordinate importance.

Older reef limestones also are characterized by extremely beautiful conical karst development. This fact is even used in photogeological studies of New Guinea for the localization of the extensive Miocene coral limestone areas. It appears to the author that the porosity of these coral limestones is a main cause of their morphological outlook. Porosity, even more than purity, apparently, is an essential lithological factor for conical karst formation. One may even wonder whether under exceptionally favourable lithological circumstances conical karst may be found outside the humid tropics. Conical karst is reported from southern Germany by Büdel[3] but palaeo-climatological conclusions are drawn from that occurrence. A thorough evaluation of both lithology and climate seems essential in further karst studies.

1. Lehmann and others, 'Das Karstphänomen in den verschiedenen Klimazonen'.
2. Verstappen, op. cit.
3. J. Büdel, 'Fossiler Tropenkarst in der schwäbischen Alb und den Ost Alpen; seine Stellung in der klimatischen Schichtstufen - und Karstentwicklung', *Erdkunde*, Vol. V, 1951, pp. 168-70.

Pseudo karst is known from the Pajakumbuh area (Plate 1), where it is carved in Tertiary conglomerates and sandstones. The cement in this case is silica. Honey-combed hill sides are characteristic for these pseudo karst hills. Another instance of pseudo karst occurs along the sea shore in abraded volcanic tuffs. The pinnacles then formed in the tuffaceous abrasion platform have such a great similarity to those formed under comparable circumstances in limestone that they cannot be distinguished from the latter at first sight. The most remarkable pseudo karst feature beyond doubt is the bioherm area near the village of Punung in southern Java, to which reference was made earlier. The limestone hills occurring there do not represent conical karst, but are the original bioherms.

SUBTERRANEAN RIVER COURSES

Occasional sinkholes in conical karst landscapes result from local solution of lime along faults and joints, or where subterranean rivers are present. The roof of such river courses gradually becomes thinner, due to the continuous solution of the caves and the sinkholes, and finally it collapses, giving rise to steep sided karst canyons. The three examples described below; from Halmahera, Central New Guinea and South-west Celebes, illustrate such development.

Figure 2, drawn from an air photograph, depicts the underground course of the Sagea River on the island of Halmahera. The river disappears when reaching the limestone plateau, and, following a course of about five kilometres more or less parallel with the southern escarpment, emerges at the foot of the latter in the

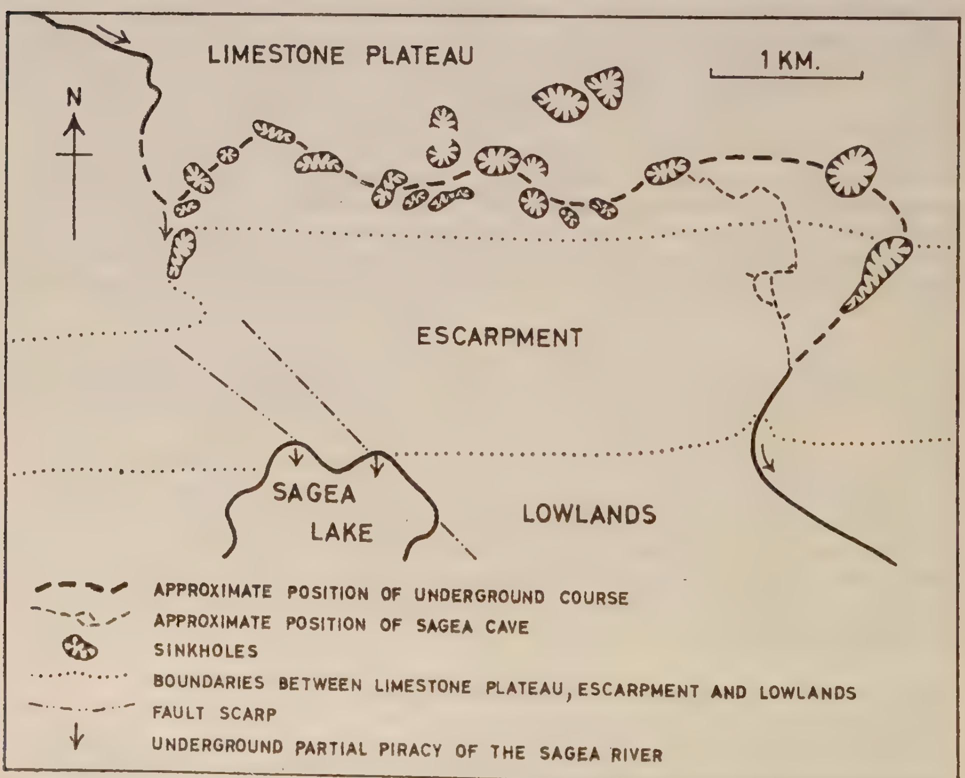

Fig. 2. The underground course of the Sagea River on the island of Halmahera, Moluccas.

hilly coastal lowlands. The location of the underground course is marked by a series of sinkholes in a landscape of ill developed, rather flat, conical hills. Formerly the river made a short cut underground as indicated.

The cave thus formed is described by Bensemann[1] and Drejer[2] as stated earlier. Drejer mentions a water filled pit at the upstream end of the cave, which is clearly a collapsed sinkhole in the subterranean Sagea course. Bensemann speaks of the fast flowing Sagea River at the same locality. From the latter description the impression may be gained that the end of the underground course is reached, which is definitely not the case, as is apparent from the air photograph.

Kükenthal visited the nearby Sagea Lake and mentions recrystallized coral limestone from the steep northern side of the lake.[3] He also refers to the occurrence of a large spring at this locality. Two fault scarps, running approximately in a north-west to south-east direction along the north-eastern side of the lake, can be clearly distinguished on the air photographs. The most eastern of these continues along the eastern shore of Sagea Bay. Both the lake and the bay are doubtless of a tectonic origin. It is most likely that the spring mentioned by Kükenthal results from an underground capture of the Sagea River along these faults, as indicated in Fig. 2, though it cannot be decided from Kükenthal's description whether the spring occurs at the western or the eastern fault scarp.

More advanced is the solution in the case of the Warok River, a tributary of the Grand Valley of the Balim River in Central New Guinea, described by Montagne.[4] The underground river here also altered its course, but the roof of the deserted cave has almost completely collapsed. The last remnant of it forms a giant natural bridge spanning the so called Olsen Hole or Shangrila (Plate 3). Its size can be judged from the trees in the cave and from the trail on the natural bridge. The ultimate stage of this development is reached by the steep sided karst canyon of the Matjao River (Plate 6), passing through the conical karst landscape of South-west Celebes near the town of Watampone. The role played by sinkholes in the development of the karst canyons in the humid tropics is evident, as appears from the above descriptions.

Karst development in the Punung area of the Sewu Mountains is especially interesting. From the geological investigations of Sartono it appears that relatively small sized coral reefs, bioherms, occur in an environment where occasional tuff beds were deposited.[5] After the ultimate emergence above sea level the tuff beds were partly eroded and the bioherms once again stood out in relief. The limestone hills in this karst area are the original bioherms rising from the tuff plain (Plate 5), and not conical karst hills. A number of conical hills is usually formed in every bioherm. The normal conical karst landscape is only found further south near the Indian Ocean, where extensive limestone beds occur.

The drainage of the bioherm area is most peculiar. Rivers cut through the bioherms in short underground courses and flow from one little tuff plain to the other. Plate 2 shows the Gedeh River entering a bioherm, whereas Plate 7 depicts the vaucluse spring where the river reappears at the other side of the hill and, in the background, the locality where it disappears into the next bioherm. The preference the rivers demonstrate for the limestone hills, even if an easy normal

1. Bensemann, op. cit.
2. Drejer, op. cit.
3. W. Kükenthal, 'Forschungsreise in den Molukken und Borneo', 1896.
4. Montagne, op. cit.
5. Sartono, op. cit.

course through the tuff plain would have been possible, indicates that the limestone offered an easier passage for the river than the tuff beds. No traces are normally found in these small caves which suggest that in former days the underground river flowed at a greater altitude. This observation makes it likely that the drainage pattern originated as underground water-flows at the level of the tuff beds. The present situation only came into being at a more advanced stage of erosion.

CONCLUSION

The chemical analyses of karst water, and especially of surface water running along lapiés, form the starting point for the above considerations about the tropical karst phenomena of the Malay Archipelago. These analyses, though easily accounting for a much quicker rate of solution of lime than in the moderate climates, cannot satisfactorily explain entirely different landforms of limestone areas in and outside the humid tropics. A climatological influence on the development of limestone areas, on the other hand, is evident from field observations. Both a temperature and a precipitation limit seems to exist for the 'conical' karst development, which is thought to be typical of the humid tropics. These limits are rather ill defined, however. Outside the tropics, negative terrain forms, such as sinkholes, are usually formed.

Observations by the author in the Malay Archipelago revealed the existence of areas characterized by a wild karstification where both positive and negative forms are intermingled. This 'labyrinth karst' forms a third type along with 'normal' and 'conical' karst. Sinkholes are also encountered in the humid tropics, especially along joints and underground rivers and preferably in compact or impure limestones. The problem thus becomes even more complicated.

It is too much of a simplification to distinguish only 'normal' and 'tropical' karst features. The diversity of karst phenomena points to a number of interacting causes. Lithology and structure definitely deserve more attention in this relation, whereas the regional geomorphic history also should be taken into account. Aligned karst features sometimes are due to joints or to the strike direction of steeply dipping limestone beds. In other cases former coastlines or river courses play a role. Porosity and purity of the limestones are of great importance, whereas relief and karst water level are other factors to be considered. All these factors combined, together with the climatological aspects, account for the diversified karst features of the Malay Archipelago.

THE RAINFALL OF MALAYA, PART II

By W. L. DALE

THE FIRST part of this study was devoted to a general description of the monthly and annual rainfall of Malaya, and included a suggested division of the country into rainfall regions.[1] It is now proposed to investigate some other features of rainfall in Malaya.

RAIN-DAYS

A rain-day is here defined as a 24-hour period, commencing at 0730 hours (0000 G.M.T.), in which 0.01 in. (0.2mm.) or more of rain is recorded.

Figure 1 shows the average number of rain-days in a year. Relief is evidently a major factor affecting the number of days with rain, although the relationship between relief and the number of rain-days is not quite the same as the relationship between relief and the annual amount of rainfall. The greatest amount of rainfall generally occurs over the foothills and adjacent lowlands rather than over the areas of highest relief, but in western Malaya, at least, the number of rain-days over the foothills and lowlands is less than at the summits of the mountains. Few lowland stations, west of the Main Range, experience as many as 200 rain-days in a year, whereas the Main Range between Cameron Highlands and Fraser's Hill, and an area on the Larut Hills, have rain on more than 200 days.

The east coast lowlands have considerably more rain-days per year than those of the west coast. The mountains of eastern Malaya, however, appear to have fewer rain-days than their relief and high annual rainfall would suggest. This may be due in part to a high intensity of rainfall during the north-east monsoon, and the sheltering effects of the Main Range during the south-west monsoon. Eastern Johore is a remarkable area in that it is the driest part of the eastern wet belt and yet has the largest number of rain-days.

The average frequency of rain-days in the western lowlands of Malaya ranges between a minimum of 134 per year at Kuala Selangor and a maximum of 223 at Taiping. For the eastern lowlands the range is from 174 at Pekan to 198 at Mersing, and at lowland stations in the interior it varies between 154 at Jelebu and 204 at Kuala Lipis.

The highest number of rain-days recorded in any one year at a lowland station was 248 at Taiping in 1957, and the lowest was 81 at Kuala Selangor in 1954.

Numerous highland stations experience more than 200 rain-days in a year. Cameron Highlands (4,759 ft.) has an average of 239 and Maxwell's Hill (3,400 ft.) 216. The average on Penang Hill (2700 ft.) is 204, compared with only 172 at Penang Town on the coast at the foot of the Hill.

The year to year variation in the number of rain-days at any one place may be considerable. For example, Penang Town had 119 rain-days in 1894 compared with 229 in 1949 — a difference of 110; Kuantan had 111 rain-days in 1940 and 226 in 1949 — a difference of 115. In general, it may be said that for any station

1. W. L. Dale, 'The Rainfall of Malaya, Part I', *Journal of Tropical Geography,* Vol. 13, 1959.

in Malaya the number of rain-days in a year is liable to vary by any value up to ± 40 per cent of the annual average.

On the Main Range, the Larut Hills and Penang Hill, from 52 to 57 per cent of the days are rain-days; along the east coast the percentage ranges from 48 to 54, whereas on the west coast it drops to between 40 and 47 per cent. This does not mean that in Malaya almost every other day is a rain-day. Wet and dry spells are frequent, and the length of such spells varies considerably. Relatively long dry spells[1] often occur in north-west Malaya. For example, in 1940 Kangar experienced a dry spell of two months (January and February), and in the same year Alor Star had only six rain-days in three months (January, February and March). Dry spells tend to become shorter with decreasing latitude. A completely dry month is a rare occurrence anywhere in Malaya south of Penang.

The average number of rain-days also varies over a larger seasonal range in the north than in the south of the country. At Alor Star the normal range is from 5 rain-days in February to 23 in October — a difference of 18 rain-days. At Sitiawan the frequency varies from 10 in June to 19 in October — a difference of 9 rain-days, and at Malacca from 8 in February to 17 in October and November — a range of 9. The distribution of rain-days at Singapore is more evenly spread through the year, with a difference of only 7 between a minimum of 12 rain-days in February and a maximum of 19 in November. A similar decrease in range from north to south is observed on the east coast, except that the range at Kota Bharu is only 13 (9 in February and April, 22 in December) compared with 18 at Alor Star.

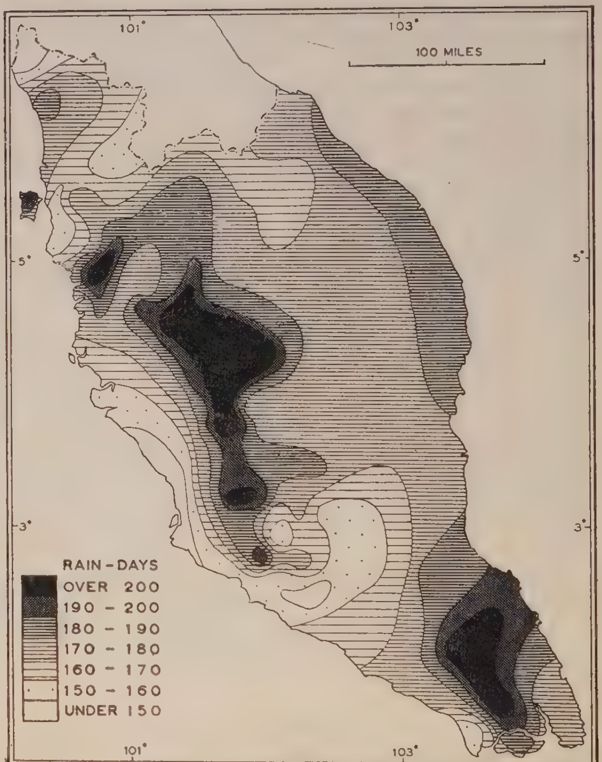

Fig. 1. Average number of rain-days per year.

DIURNAL VARIATION OF RAINFALL

The incidence of rainfall varies considerably in its distribution throughout the day. Over the sea the maximum frequency of precipitation normally occurs in the early morning, but over the land the maximum is usually recorded during the afternoon, although in coastal districts it may occur at different times of the day or night according to the season. The early morning maximum over the sea has a

1. For definition of 'dry spell' see section on 'Dry Spells' below.

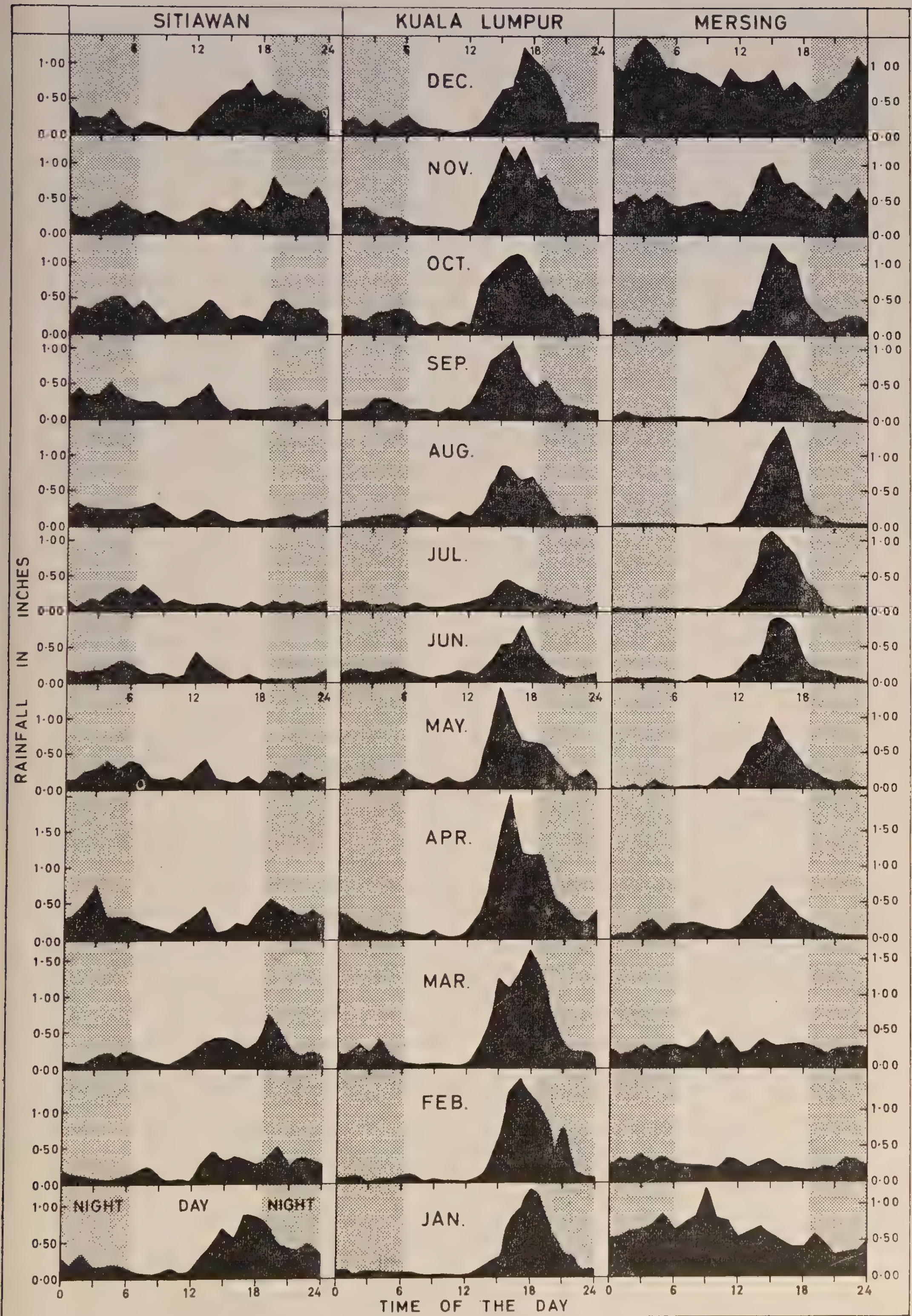

Fig. 2. Diurnal variation of rainfall at Sitiawan, Kuala Lumpur and Mersing.

marked influence upon the diurnal pattern of rainfall in coastal areas. Distant inland places are not affected in this way.

Three patterns of diurnal rainfall may be distinguished in Malaya: (1) west coast type; (2) east coast type; and (3) inland type. Figure 2 shows the hour by hour pattern of rainfall for stations typical of these three types.

(1) *West Coast Type.* The daily cycle of rainfall along the west coast varies according to the prevailing monsoon. During the south-west monsoon the maximum fall occurs during the morning, and a minimum is recorded in the afternoon. With the advance of the north-east monsoon the mornings become relatively dry and the afternoons wet.

Figure 2 shows the diurnal variation at Sitiawan which may be regarded as generally typical of the west coast of Malaya. From May until September, the south-west monsoon period, rainfall peaks may occur at almost any hour of the morning, whilst the afternoons are much drier. Throughout the north-east monsoon, November to March, the rainiest part of the day is from noon until midnight with a peak period between 4 and 6 p.m. The peak tends to be an hour or so earlier southwards from Sitiawan and an hour or so later to the north. In February, however, two maxima falls may be experienced, one between 1 and 2 p.m. and the other as late as 7 to 8 p.m. During the transitional months, April and October, high peak falls occur early in the morning — between 2 and 5 a.m., at noon and again between 6 and 8 p.m.

The morning maximum on the west coast during the south-west monsoon is due, at least in part, to the development of rain-bearing clouds over the Straits of Malacca during the night. These are formed by the relatively cool air of land breezes undercutting unstable air over the sea forcing the warm moist sea air to rise. Cumulonimbus clouds develop, which, under the influence of the prevailing south-westerly air-stream, drift landwards when the land breeze dies away and bring rain to a narrow coastal belt. Such showers account for the high morning frequency of rain along the west coast for several months during the south-west monsoon. The showers are often re-inforced by strong squalls known as *Sumatras*. 'These squalls form over the Straits of Malacca at night, the radiational cooling of cloud tops probably helping to provide the instability for cumulonimbus formation.'[1]

The afternoon peaks of rainfall on the west coast during the north-east monsoon are associated with light winds or calm conditions and the diurnal heating of the land, favouring the fall of convectional rain. The prevailing off-shore north-easterly wind prevents sea showers from moving inland in the mornings.

(2) *East Coast Type.* The east coast of Malaya also experiences a diurnal regime which changes with the monsoon. But here the maximum fall of rain during the north-east monsoon (December to March) occurs in the night or early morning, due to the landward drift of showers from the South China Sea, and during the south-west monsoon the maximum fall is received in the afternoons.

The morning maximum is particularly pronounced in December and January. In February and March the fall is more evenly distributed through the day, though the morning peak is still present. The time of the morning maximum varies between 2 and 9 a.m., and in the afternoon a minimum occurs between 6 and 9 p.m. Although the mornings are wetter than the afternoons no hour of the day or night can be described as always dry.

1. I. E. M. Watts, *Equatorial Weather* (London, 1955), p. 71.

Throughout the south-west monsoon and both transitional periods, that is from April to November inclusive, the cycle is reversed. The mornings, up to 11 a.m., are characterized by low rainfall whilst the afternoons show a pronounced maximum sometime between 2 and 6 p.m. The afternoon maximum tends to occur earlier in the south than in the north.

The graph for Mersing (Fig. 2) displays the main characteristics of the east coast diurnal cycle of rainfall. A striking feature at Mersing is the very small amount of rain that falls between 11 p.m. and 11 a.m. during the south-west monsoon when showers from the sea are unable to move inland. From June until September the fall during this part of the day is almost negligible. The peak fall between 3 and 4 p.m. in August reaches an average total for the month of 1.4 inches, which is the highest total of rainfall for any hour of the day throughout the year. Also in August the rainiest part of the day is usually restricted to only seven hours between 11 a.m. and 6 p.m. during which period 90 per cent of the day's rain is received.

(3) *Inland Type.* For most inland stations, beyond the range of penetration of coastal showers, the daily rainfall cycle retains the same general pattern throughout the year. The morning hours are relatively dry, especially between 8 and 11 a.m., whilst the hours from noon until shortly before midnight are much rainier. The peak period varies from place to place, but in general it occurs sometime between 2 and 8 p.m. On the western side of the Main Range the afternoon maximum is particularly pronounced during the north-east monsoon and the intermonsoonal months. The distribution at Kuala Lumpur is fairly typical of inland stations. The mornings are relatively dry, but from noon onwards the frequency of rain increases rapidly to a peak sometime between 4 and 6 p.m. during the north-east monsoon (December to March), and between 2 and 5 p.m. during the remainder of the year. After reaching the peak there is a steep fall to a low rainfall period commencing any time between 9 and 11 p.m.

COEFFICIENT OF VARIABILITY (Figs. 3, 4, 5 and 6)

The percentage deviation from the mean monthly rainfall, sometimes referred to as the Coefficient of Variability (CV),[1] is normally greatest for the month with the lowest rainfall and least for the month with the highest rainfall. Whilst this rule is generally true for western Malaya, it is not entirely valid in eastern Malaya as will be observed later.

In the *North-west Region* the coefficient of variability is greatest during the relatively dry months of December, January and February. Thus, for example, the value for CV at Kangar (Perlis) is 110 per cent in January — the month with the lowest average rainfall of 1.74 inches, and 89 per cent in February. At Alor Star (Kedah) the highest value of CV for the year is 89 per cent in February when the average rainfall is 2.05 inches — the lowest for the year at that place.

For eight months of the year, from April until November, at most places north of latitude 5°N in western Malaya, CV is less than 50 per cent, except that in July the value for CV may rise to 70 per cent in the southern part of the north-

1. $CV = \frac{100d}{M}$, where CV = Coefficient of Variability, d = standard deviation and M = the mean value of rainfall. The Standard Deviation is obtained from the formula $dx = \sqrt{\frac{\sum(x_n^2)}{N}}$ where d = standard deviation, x_n = deviations from the mean, and N = the total number of observations upon which the mean is calculated.

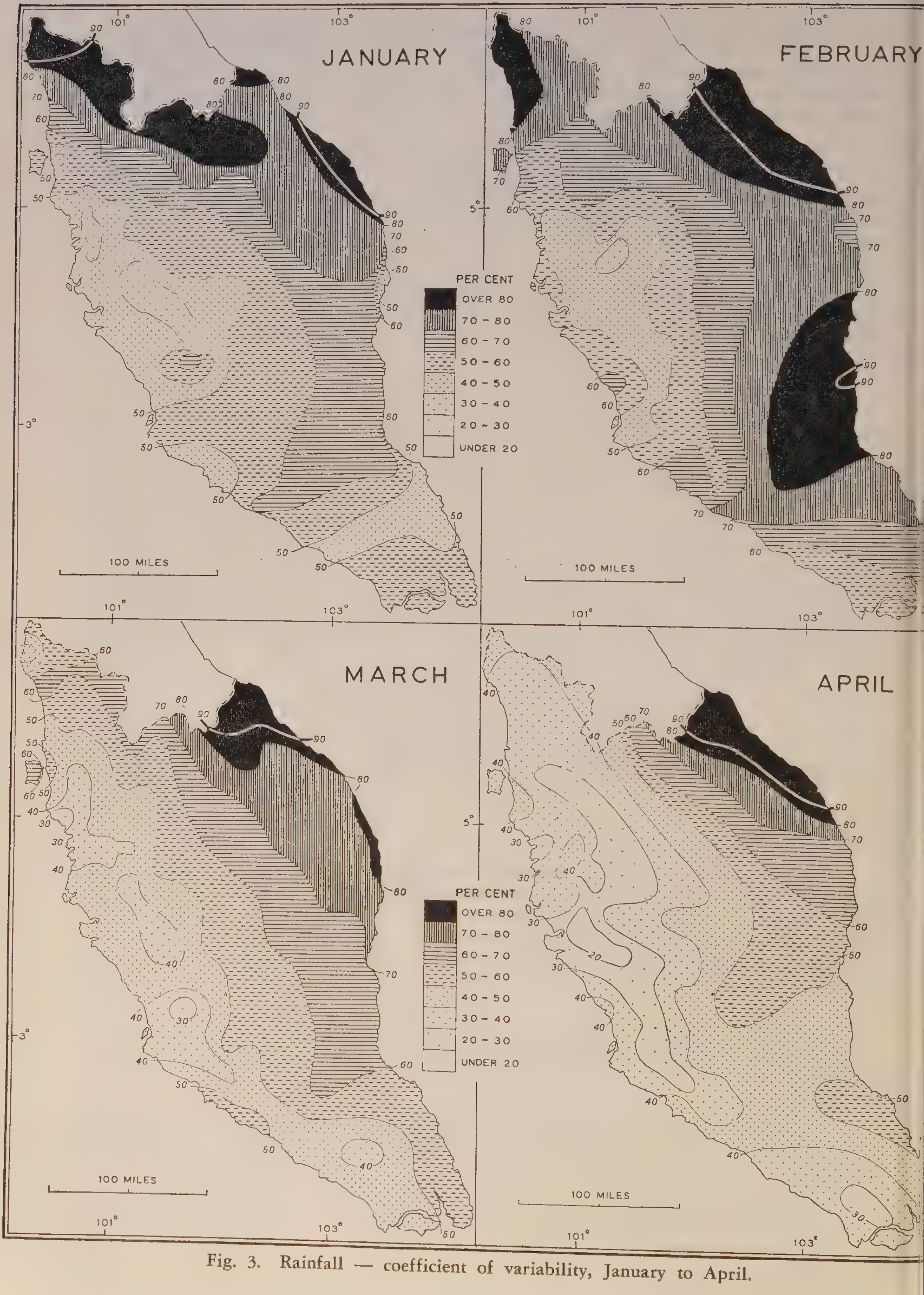

Fig. 3. Rainfall — coefficient of variability, January to April.

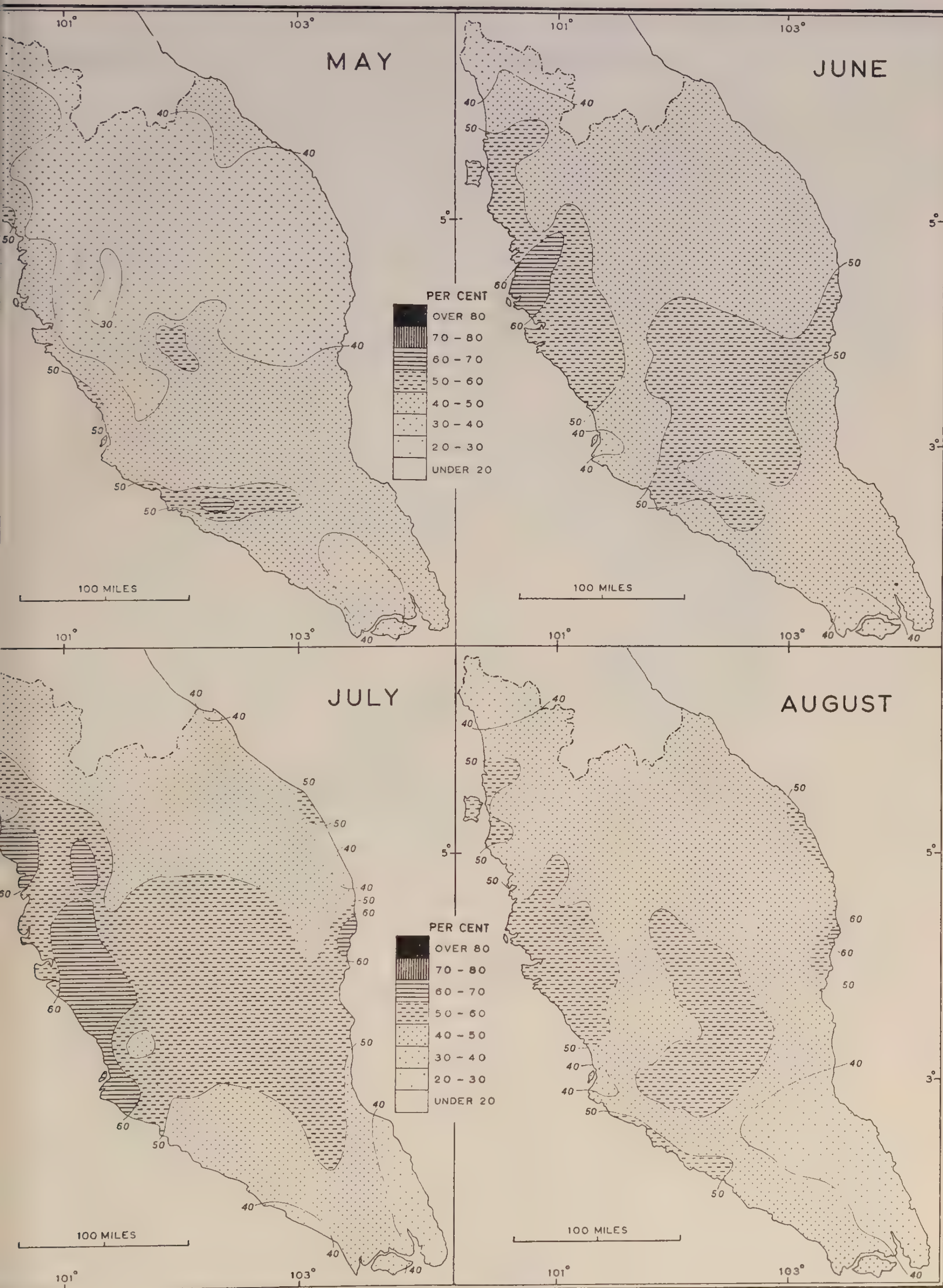

Fig. 4. Rainfall — coefficient of variability, May to August.

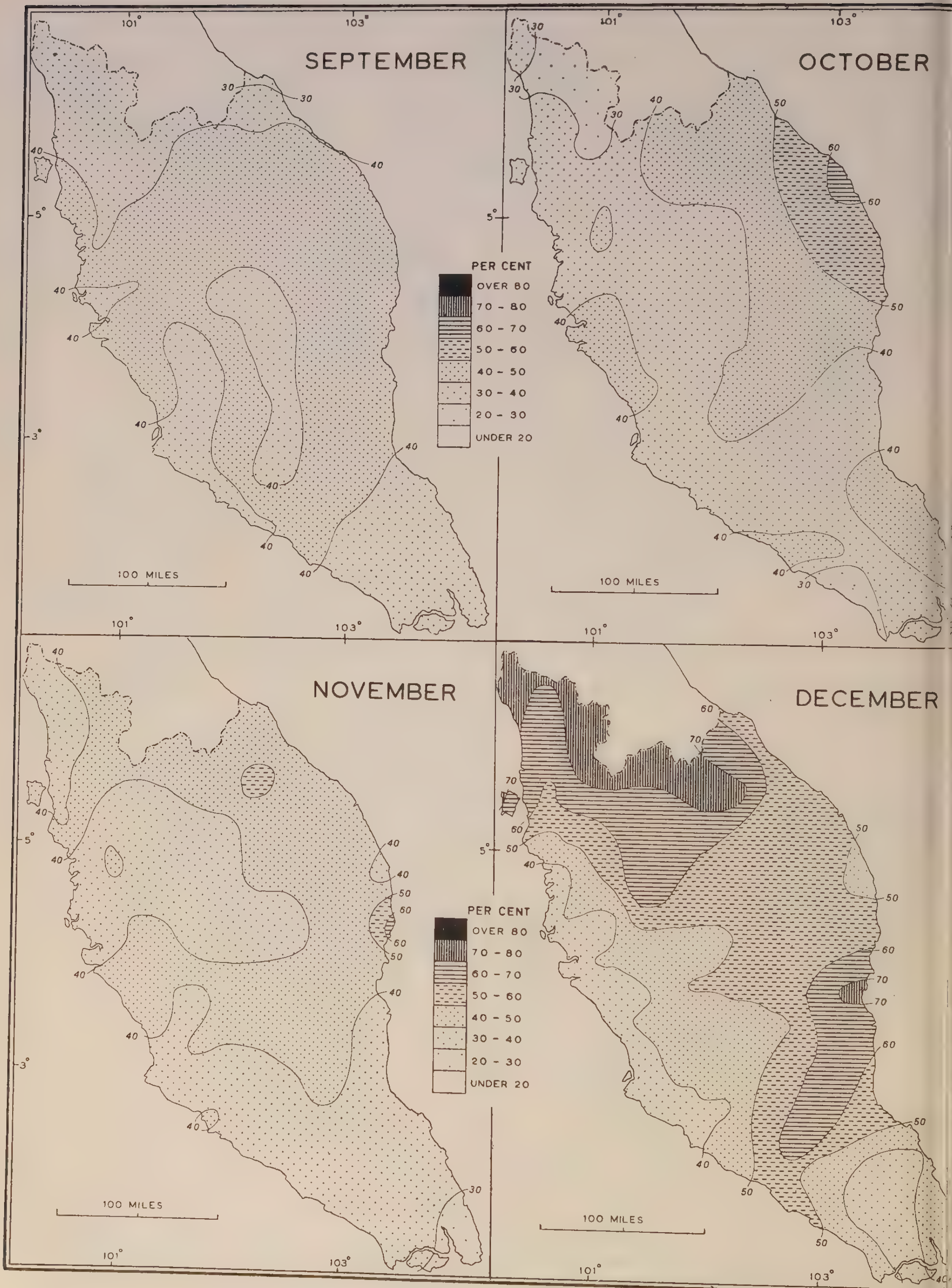

Fig. 5. Rainfall — coefficient of variability, September to December.

west region. The minimum value often coincides with the inter-monsoonal months when rainfall is high. Thus at Alor Star CV falls to its lowest value of 29 per cent in October — the month with the highest rainfall.

In the *West Region* the percentage deviation from the mean is greatest in June and July, which are the driest months for most places in this region. During these months CV ranges between 50 and 70 per cent. The lowest values for CV occur during the inter-monsoonal months when rainfall is normally at a maximum. In April and October most of the west region has a value for CV of less than 40 per cent. Over an extensive area to the south-east of Sitiawan it falls to well below 20 per cent in April, this is the lowest monthly figure for CV so far observed in Malaya.

Throughout the *Port Dickson — Muar Coastal Region* the minimum of rainfall and the highest value for CV occur in February. At this time CV rises to 60 or 70 per cent. The rainfall maximum occurs in October and the lowest value for CV is recorded in the months of October and November when it is below 40 per cent.

In the *South-west Region* rainfall is more evenly distributed throughout the year so that values for CV display a smaller range. February and July are relatively dry months, but the rainfall variability is considerably greater in February than July. The July figures for CV are in fact surprisingly low — they are little different from those for the months of April and October when rainfall is at its maximum.

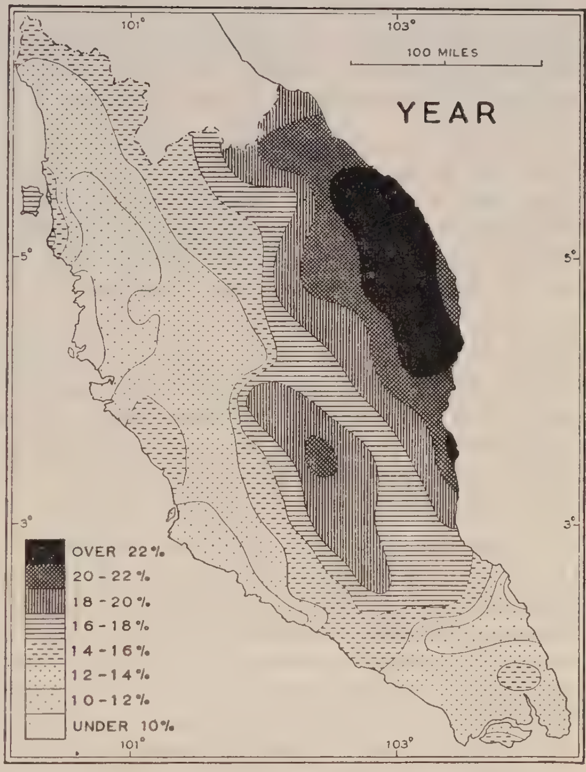

Fig. 6. Rainfall — annual coefficient of variability.

At Batu Pahat the monthly rainfall totals range between a minimum of 6.03 inches in February and a maximum of 9.69 inches in November. The extreme values for CV at this station are 54 per cent in February and 36 per cent in November.

In the *East Region* the relationship between the amount of rainfall and the value for CV departs, to some extent, from the general rule observed in western Malaya. On the east the wettest months are November, December and January, whilst the months from February to September are relatively much drier. The coefficient of variability during December and January is remarkably high. In December CV is almost everywhere more than 50 per cent, and reaches a maximum for the month of 74 per cent at Kuantan. In January it is generally above 60 per cent, and rises to a maximum of 113 per cent at Kuala Trengganu. The only

other part of Malaya with such an outstanding rainfall variability is the north-west region where the January values for CV exceed 90 per cent. But December and January are relatively dry in the north-west, whereas they are wet months in the east.

February is a relatively dry month on the east, and it is in this month that the region as a whole experiences its greatest variability. Only in the extreme south does CV fall below 60 per cent at this time. Values of over 100 per cent occur along the coasts of Kelantan and Trengganu. In Kelantan CV remains high until the end of April, but elsewhere on the east the variability decreases throughout March and April, until the month of May when CV is about 40 per cent. The variability tends to increase slightly in June, July and August, but falls again in September. A slight rise is observed in October in the north-east, but by November it has fallen again. In December, the wettest month over much of the east region, the variability shows a marked rise, except in Johore where it continues to remain relatively low until February.

Eastern Johore and Singapore do not experience the wide range of variability of the rest of the east region. Thus at Singapore the value of CV ranges between 54 per cent in January and February (average monthly rainfall totals being 9.93 and 6.87 inches respectively) and 29 per cent in November (average monthly rainfall 9.89 inches). In this instance the month with the lowest CV has a rainfall about equal to that of the month with the highest CV.

It is evident that no simple rule can be applied to the relationship between rainfall and variability in the east region. At Kota Bharu, to quote another example, the highest value for CV is 121 per cent, which occurs in April — the month with least rainfall (4.6 inches), but the lowest value for CV does not occur in December — the wettest month, it occurs in September when the average rainfall is 8.27 inches and CV is then 30 per cent. In December the average rainfall is 26.09 inches and CV 51 per cent.

The percentage deviation from the mean annual rainfall is shown in Fig. 6. The highest variability occurs in north-east Malaya where the States of Kelantan, Trengganu and Pahang have values for CV of between 20 and 23 per cent. This area approximately coincides with that of the highest annual rainfall (over 140 inches per annum) in Malaya.[1] The second area with a high CV for the year is in central Pahang where CV rises to 20 per cent in the Temerloh District. This second area of high variability is one of Malaya's driest parts (less than 90 inches per annum), which is a striking contrast with the first area of high variability.

There are three areas in which the annual values for CV are relatively low :— (1) the lowlands of South Perak where CV falls to 9.5 per cent (at Sitiawan); (2) the west coast from Port Swettenham to Malacca, and (3) the Mersing coast and hinterland. The average annual figure for CV at Mersing is 9.6 per cent.

The highest annual value for CV in western Malaya is 18.6 per cent at Penang. The highest figure for a station on the western mainland is 15.7 per cent at Muar.

Along the summit of the Main Range variability is relatively low. The annual values for CV at Cameron Highlands and Fraser's Hill are 12.3 and 12.9 per cent respectively.

1. Dale, op. cit., Fig. 2, p. 25.

RAINFALL INTENSITY

Average Intensities

The distribution of rain-days through the year follows the same general pattern as the monthly rainfall, except that as the monthly total rises so the intensity[1] increases (Fig. 7). Thus, for example, the difference between the average rainfall at Pekan in October and December is 15 inches, but the number of rain-days in the two months differ only by one day.

Average intensities tend to rise and fall according to a seasonal rhythm, though the rhythm varies from region to region, and in some instances it varies considerably within a region. The seasonal rise and fall of intensities is most marked in the north-west and east regions (Table 1).

The highest average intensities in the *North-west Region* are experienced in September or October and the lowest in January or February. Some places, however, have a secondary maximum in March or April. An average intensity of 0.89 inches per rain-day at Kulim in October is the highest so far recorded in the western lowlands of Malaya.

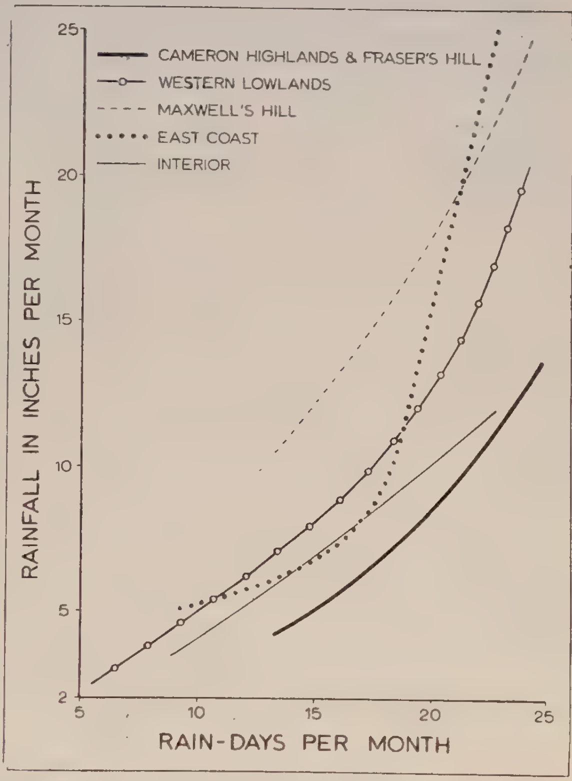

Fig. 7. Rainfall — average intensities. The 'interior' includes such stations as Kuala Lipis, Raub, Temerloh and Jelebu.

In the *East Region* the highest average intensities occur during the north-east monsoon. Figure 7 shows a remarkable increase of intensity at east coast stations when the average monthly rainfall exceeds 7 or 8 inches, that is from October to January for most places. North of Pekan high intensities are usual in November and December, whilst to the south they are more frequent in December and January. The highest average intensity is 1.29 inches per rain-day at Pekan in December. Minimum average intensities occur in different months, but usually between April and July. The range between the average maximum and minimum intensities is greatest in the east region. Thus at Kuala Trengganu the average intensity in November is three times that for July. In Malaya as a whole the range normally decreases from north to south.

High average intensities in that part of the *West Region* which lies to the north of Kuala Lumpur are usual in October, November or December. South of

1. Intensity is here obtained from the formula $I = \frac{A}{N}$ where I = intensity of rainfall, A = the total rainfall per month and N = the total number of rain-days in the same month.

TABLE 1: AVERAGE INTENSITY OF RAINFALL

PLACE	LOCATION	MAXIMUM		MINIMUM	
		Inches per rain-day	Month	Inches per rain-day	Month
Alor Star —	North-west	0.64	Sep.	0.32	Jan.
Baling —		0.69	Oct. Apr.	0.49	Aug.
Penang —		0.85	Sept.	0.38	Feb.
Kulim —		0.89	Oct.	0.52	Feb.
Taiping —	West	0.84	Oct.	0.58	Jun.
Ipoh —		0.65	Dec.	0.45	Aug.
Sitiawan —		0.49	Nov. Dec. Jan.	0.31	Jul.
Kuala Selangor —		0.62	Dec.	0.43	Mar.
Kuala Lumpur —		0.55	Mar.	0.37	Jul.
Seremban —		0.54	Apr.	0.37	Jan.
Port Dickson —		0.73	Aug.	0.43	Jan.
Malacca —		0.61	Jun.	0.40	Jan.
Batu Pahat —	South-west	0.64	Aug.	0.47	Dec.
Kluang —		0.58	Jan.	0.31	Jul.
Johore Bahru —		0.65	Jan.	0.46	Oct.
Kota Bharu —	East	1.18	Dec.	0.40	Jul.
Kuala Trengganu —		1.17	Nov.	0.39	Jul.
Kuantan —		1.07	Dec.	0.45	May
Pekan —		1.29	Dec.	0.44	May
Mersing —		0.91	Dec.	0.36	Apr.
K. Tinggi —		0.94	Jan.	0.46	Jul.
Singapore —		0.58	Jan.	0.45	May
Kuala Lipis —	Interior	0.57	Oct.	0.40	Feb. Mar.
Bentong —		0.61	Dec.	0.40	Jul.
Temerloh —		0.53	Oct.	0.21	Jul.
Jelebu —		0.53	Mar.	0.34	Aug.
Kuala Pilah —		0.51	Mar.	0.33	Jul.
Segamat —		0.68	Jan.	0.36	Aug.
Maxwell's Hill —	Hill Stations	1.16	Sep.	0.76	Jan.
Cameron Highlands —		0.54	Nov.	0.32	Jul.
Fraser's Hill —		0.56	Nov.	0.32	Aug.

Kuala Lumpur they normally occur in March or April. Low intensities are characteristic of the south-west monsoon, especially the months of July and August.

Coastal localities in the *South-west Region* appear to experience their highest average intensities during the south-west monsoon and lowest intensities in the north-east monsoon, as at Batu Pahat. However, inland from the coast the highest intensities tend to occur in the north-east monsoon or in March or April and the south-west monsoon is characterised by low intensities.

The *Port Dickson — Muar Coastal Region* has higher intensities in the south-west monsoon than during the north-east monsoon.

Maximum Intensities

Average intensities, based upon the rainfall per rain-day, fail to reveal the very intense falls of rain experienced at irregular intervals and for only a few minutes or a few hours. Short heavy downpours, rather than long spells of continuous rain, are characteristic in Malaya. The highest maximum intensities occur

along the east coast, where very heavy falls are likely to be received during the north-east monsoon. Over the lowlands of western Malaya short heavy falls may occur in any month. At several places some of the highest intensities have been recorded in February which is normally the month with a minimum of rainfall.

In Fig. 8 the graphs for Kota Bharu (10 ft. above sea level) and Alor Star (15 ft. above sea level) may be taken as fairly representative of eastern and western Malaya respectively. It will be observed that the maximum intensities on the east are considerably superior to those on the west for the longer periods of duration. Thus at Kota Bharu the maximum intensity for a twelve hour period was 12.63 inches (= 0.0175 inches per minute), compared with that at Alor Star of 5.97 inches (= 0.0083 inches per minute). For a ninety-six hour period the highest maximum at Kota Bharu was 28.29 inches (= 0.0049 inches per minute), and at Alor Star 9.58 in (= 0.0016 inches per minute). For short periods of up to one hour the maximum intensities at both places were similar.

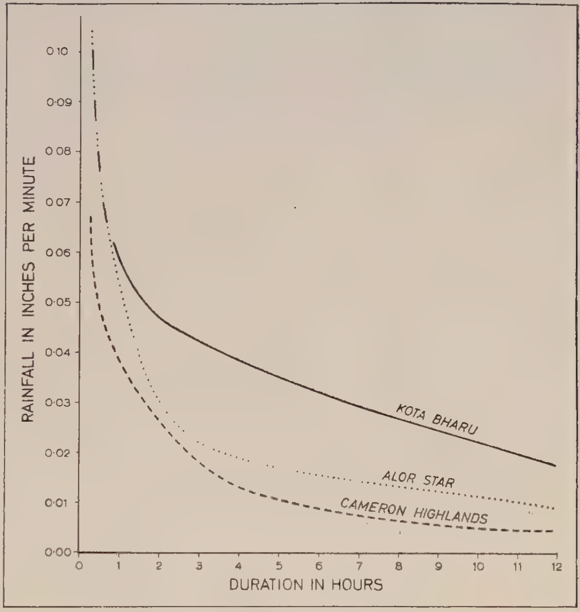

Fig. 8. Rainfall — maximum intensities.

An exceptionally high maximum intensity occurred at Kuala Lumpur (127 ft. above sea level) on 24th February 1951 when 2 inches of rain fell in 15 minutes (that is a fall of 0.133 inches per minute). It is seldom that an intensity of this magnitude is exceeded anywhere in Malaya.

On the highlands, maximum intensities are considerably lower than in the lowlands, as is evident from the graph for Cameron Highlands (4.750 ft.).

DRY SPELLS

The term *dry spell* is used here to refer to a period during which less than 0.01 inches of rain falls per day for a number of consecutive days. Dry spells of seven days and above have been tabulated for various coastal and inland stations in Tables 2 to 6. These have been prepared from the hour by hour rainfall records for the places concerned.

Although no part of Malaya has a definite regular dry season, all parts are liable to periodic dry spells of variable length. The length of the dry spells varies with latitude and with the time of the year. They are longer and more frequent in the north than in the south, but the time of the year in which they are longest and most frequent varies from region to region.

The longest and most frequent dry spells are experienced in the *North-west Region.* A remarkably long dry spell occurred at Alor Star during January and

February 1940, when no rain fell for 49 days.[1] Periods of 21 days without rain are relatively frequent at Alor Star — 16 occurrences in 23 years, and dry spells of 14 days are very frequent — 46 occurrences in 23 years. In the extreme north-west the months of December, January and February are particularly liable to dry periods, but for the rest of the year a spell of ten consecutive days without rain is relatively infrequent. Southwards, however, the length and frequency of dry

TABLE 2: DRY SPELLS — ALOR STAR AND PENANG

Number of Consecutive days without rain	Number of Occurrences											
	J	F	M	A	M	J	J	A	S	O	N	D
ALOR STAR — 23 yrs. 1930 to 39; 1940, 7, 8, 9; 1950 to 58.												
31												1
30												1
29		1										1
28	1	1										1
27	1	1										1
26	2	1										1
25	2	1										1
24	2	1										1
23	3	1										1
22	3	2										1
21	5	2										2
20	5	5										2
19	5	5										3
18	6	7										3
17	8	7	1									3
16	9	7	2									3
15	12	10	3									4
14	14	12	4			1						6
13	15	13	4			1						6
12	16	17	5			1	2					9
11	19	19	7			1	2		1		1	12
10	26	22	8			2	4	3	1		1	16
9	31	29	10	1	1	4	4	5	1	1	3	20
8	40	34	13	3	3	8	5	6	2	1	5	23
7	50	43	19	6	5	10	11	9	4	2	7	31
PENANG — 18 yrs. 1934 to 39; 1940, 8, 9; 1950 to 58.												
24	1											
23	1											
22	1											
21	1											1
20	1					1						1
19	1					1						1
18	1	1				1						2
17	2	1				1						3
16	2	1				1						3
15	2	2				1						3
14	3	2				2						3
13	4	2	1			2						4
12	5	3	1			2		1			1	5
11	9	4	1			5		2			1	5
10	10	7	1			6		4			1	11
9	11	9	2			7	1	4	1		3	14
8	16	11	3	1	1	10	4	5	2		3	15
7	21	14	6	3	2	15	9	6	2	1	5	20

1. Many of the lengths of dry spells given in the text of this article overlap two or even three consecutive months. The duration of such dry spells will not be evident from Tables 2 to 6 which only show those dry spells that have occurred within the limits of each month.

spells decrease rapidly so that at Penang the longest dry period in 18 years was 24 days.[1] There is also a gradual change in the distribution of dry periods throughout the year. Whilst December, January and February are still very liable to dry spells, June is also a month when dry spells are relatively frequent.[2]

Dry spells are short and infrequent in the north-west in April, May, September and October. During these months a week without rain is exceptional.

TABLE 3: DRY SPELLS — SITIAWAN, KUALA LUMPUR AND MALACCA

Number of Consecutive days without rain	Number of Occurrences											
	J	F	M	A	M	J	J	A	S	O	N	D
SITIAWAN 23 yrs. 1931 to 39; 1940, 6, 7, 8, 9; 1950 to 58.												
23						1						
22						1						
21						1						
20						1						
19						1						
18						1						
17	1					1						
16	1					2	2					
15	1	1				2	2					
14	2	1				2	6					
13	2	2			1	4	6	1	1			
12	2	3			2	6	7	1	1			
11	2	4			2	11	8	2	1			1
10	4	7			4	13	9	4	2			1
9	4	8			5	16	10	6	3			3
8	7	9	2	1	5	20	16	12	4	3	1	7
7	12	16	5	3	9	25	24	17	4	4	2	10
KUALA LUMPUR 24 yrs. 1927, 8, 9; 1930 to 38; 1940, 8, 9; 1950 to 58.												
17						1						
16						1	1	1				
15						1	2	1				
14		1				1	2	1				
13		1			1	1	2	1				
12		2			2	2	2	2				
11	1	2			3	4	3	2	1			
10	2	3			3	5	6	3	2			
9	4	3			3	5	7	5	2			
8	4	3			4	6	13	8	2	1	1	
7	6	4	1	1	4	12	19	9	4	1	1	4
MALACCA 23 yrs. 1930 to 39; 1940, 7, 8, 9; 1950 to 58.												
19	1											
18	1	1										
17	1	1										
16	4	2			1							2
15	4	3			1							2
14	5	4			1							2
13	5	4			1	2	1					2
12	5	6	1	1	1	2	2					2
11	6	6	3	1	1	2	2					3
10	10	8	5	2	1	2	3					5
9	11	12	7	2	2	3	4			1		8
8	16	16	9	3	7	4	5		2	1		11
7	21	23	10	6	7	7	5	1	4	2	1	13

1. Two 24-day dry spells occurred during the 18 years.
2. It should be observed that in Table 2 the figures for Alor Star refer to a period of 23 years whereas those for Penang are for only 18 years.

In the *West Region* dry spells rarely exceed 28 days. At Sitiawan, over a period of 23 years, the longest interval without rain was 26 days, and dry spells of 14 days duration occurred 19 times. The months in which dry periods are longest and most frequent are June, July and August, but January and February are also liable to experience dry spells though they tend to be shorter and less frequent. A minimum of dry spells occurs during the inter-monsoonal periods of March/April and October/November. Thus in this region the south-west monsoon is characterised by longer and more frequent dry spells than the north-east monsoon, whereas in the north-west region the north-east monsoon has the longer and more frequent dry spells.

Still further south, in the *Port Dickson-Muar Region,* the dry spell season coincides with the north-east monsoon, as in the north-west region. December, January and February may occasionally experience intervals of up to 20 days without rain, whilst during the months of August, September, October and November a spell of even seven days without rain is an unusual occurrence (Table 3, Malacca).

The longest dry period in 23 years at Malacca was 25 days.

Dry spells of more than 21 days duration are rare in the *South-west Region.* At Batu Pahat five 14-day dry spells occurred in 10 years; at Kluang six in 13

TABLE 4: DRY SPELLS — KLUANG AND BATU PAHAT

Number of Consecutive days without rain	Number of Occurrences											
	J	F	M	A	M	J	J	A	S	O	N	D
KLUANG 13 yrs. 1929 to 39; 1940, 1.												
22		1										
21		1										
20		1										1
19		1										1
18		1										1
17		1										1
16		1										1
15		1										1
14		1			1							1
13		2			1							1
12		3			1							1
11	2	4			1	1						1
10	4	7	1		1	1	1					3
9	4	10	2		1	1	2					3
8	5	10	3		1	2	4		1		1	3
7	7	16	4	2	3	4	6	1	1	0	1	4
BATU PAHAT 10 yrs. 1949 to 58.												
20					1							
19					1							
1					1							
17					1							
16					1							
15		1			1							
14		1			1	1						1
13	1	1			1	1						1
12	1	1			1	1						1
11	1	1		1	1	1	2					1
10	1	2		1	3	1	4					1
9	2	3		1	3	2	5	2	1		1	1
8	2	3	1	3	3	3	6	3	3	1	2	1
7	4	5	2	3	5	6	6	6	3	2	4	3

years and at Tangkak six in 10 years. The monsoons are more liable to dry spells than the inter-monsoonal periods, but neither monsoon is everywhere liable to more dry spells than the other. At Batu Pahat slightly more and longer dry spells occur in May, June and July, whereas at Kluang, December, January and February are more liable to dry periods, especially February (Table 4).

At stations in central Malaya the same general pattern as that of the west and south-west regions holds good; the monsoons being subject to more dry spells than the inter-monsoonal periods, but the frequency and length of dry spells is in some places greater in the north-east monsoon, whilst in others it is greater during the south-west monsoon. Thus at Kuala Lipis (Table 5), July is more liable to dry periods than any other month, but February comes second in order of liability. It is interesting to observe that at Kuala Lipis neither April nor November have experienced a spell as long as 7 days without rain, in 17 years. At Temerloh, 50 miles south of Kuala Lipis, February stands out as the month most liable to dry spells, with July taking second place.

TABLE 5: DRY SPELLS — KUALA LIPIS AND TEMERLOH

KUALA LIPIS — 17 yrs. 1930 to 39; 1940, 7, 8, 9; 1950 to 52.

Number of Consecutive days without rain	J	F	M	A	M	J	J	A	S	O	N	D
24							1					
23							1					
22							1					
21							1					
20							1					
19							1					
18							2					
17		1					3					
16		1				1	3		1			
15		1				1	3		1			
14		1				1	4		1			
13		1				1	4		1			
12		1	2			1	6	1	1	1		
11		2	2		1	1	7	1	1	1		
10		2	2		1	1	8	1	1	1		
9	1	6	5		1	2	9	1	2	1		
8	2	9	5		2	5	13	3	3	2		1
7	3	13	7	0	3	10	15	5	5	2	0	3

TEMERLOH — 17 yrs. 1929 to 39; 1940, 8, 9, 1950 to 52.

Number of Consecutive days without rain	J	F	M	A	M	J	J	A	S	O	N	D
19		1					1					
18		1					1					
17		1					1					
16		1					1					
15		4					2					
14		4					3					
13		4	1			1	3					
12		4	1			1	4					
11		6	2			3	4					1
10	1	6	3	1		4	4	3	1			2
9	2	10	5	2		7	5	5	2			3
8	3	11	7	2	1	9	8	6	2	1		4
7	5	18	11	3	3	10	15	7	3	2	3	6

Number of Occurrences

Along the coast of the *East Region* (Table 6), dry spells vary in length from a maximum of 45 days without rain (in 22 years) at Kota Bharu in the north, to a maximum of 23 days (in 22 years) at Kuala Trengganu and 21 days (in 24 years) at Mersing in the south. Dry spells are longest and most frequent at most places during the months of February, March and April. The length and frequency of dry spells during the south-west monsoon is remarkably small; but it is probable that inland from the east coast both monsoons are accompanied by more frequent dry spells, whilst the inter-monsoonal months are relatively free as in the west and south-west regions.

TABLE 6: DRY SPELLS — KOTA BHARU AND MERSING

Number of Occurrences

KOTA BHARU

22 yrs. 1930 to 39; 1940, 8, 9; 1950 to 58.

Number of Consecutive days without rain	J	F	M	A	M	J	J	A	S	O	N	D
31			1									
30			1									
29			1									
28			1									
27			2									
26			2									
25			2									
24			2									
23			2									
22			2									
21			3									
20			3									
19			3									
18			3	2								
17		1	5	3								
16		1	5	3								
15		2	6	5								
14		3	6	5								
13		4	10	8								
12		5	12	9			1					
11	2	7	13	9	1		2					
10	3	9	17	12	1	1	2	1			1	
9	5	11	21	15	5	3	3	6	1		1	2
8	8	17	27	20	9	5	5	9	2		1	2
7	9	31	34	27	12	6	7	13	5	1	2	4

MERSING

24 yrs. 1929 to 39; 1940, 7, 8, 9; 1950 to 58.

Number of Consecutive days without rain	J	F	M	A	M	J	J	A	S	O	N	D
21								1				
20								1				
19								1				
18								1				
17		1				1		1				
16		1	1			1		1				
15		2	2			1		1				
14		2	2	1		1		1				
13		3	3	3		1		1				
12		4	5	3	1	2		1				
11	1	5	8	3	1	2	1	1				
10	2	8	8	4	1	2	2	2			1	
9	3	11	11	5	4	5	2	3	1	1	1	1
8	3	18	18	6	4	6	4	3	1	2	1	2
7	7	24	20	13	7	7	7	4	4	4	1	3

SOME CLIMATIC IMPLICATIONS IN THE MID-FEBRUARY (1959) TROPICAL CYCLONE OVER EASTERN AUSTRALIA

By EUGENE A. FITZPATRICK

A SEVERE tropical cyclone in mid-February of 1959 crossed the central Queensland coast bringing with it exceptionally strong winds and torrential rains, which caused widespread flooding as far south as central New South Wales. In the Bowen area, which lay in the direct path of the cyclone during the period of its greatest intensity, property damage was estimated at more than one million pounds. Wind gusts as high as 116 miles per hour were recorded at Bowen, and record twenty-four-hour falls of over 10 inches of rain were reported from several stations in central and southern Queensland.

Apart from the damage it caused, the cyclone is of considerable climatological interest in that it throws light upon certain general characteristics of the rainfall of eastern Queensland and north-eastern New South Wales. Although much less spectacular and much less publicized than the direct damages resulting from the storm, the ultimate economic gains from widespread rains beneficial to stock and agriculture more than offset the immediate losses.

The path of the cyclone between the 14th and the 19th of February, and the daily position of its centre at 9 a.m., are shown in Fig. 1A. The shaded area indicates the overall extent of rainfall directly associated with the tropical cyclone between 9 a.m. on the 16th and 9 a.m. on the 19th.

A very graphic picture of the development, structure and movement of the cyclone, as well as some of its damaging effects, is given in the following description;

'From 12th to 15th a severe tropical cyclone moved westward across the Coral Sea towards Willis Island where wind gusts to eighty-four miles per hour were recorded at 9 a.m. 15th. Gaining intensity during the 15th and 16th, it moved west-south-west to south-westwards onto the Queensland coast near Ayr and then south-east to south and crossed the coast about 6 p.m. 16th near Gumlu (about half way between Bowen and Home Hill), the lowest barometer reading being 28.23 inches (956 millibars) at Bowen.

Severe winds battered Ayr, Home Hill, Bowen and Proserpine with property damage totalling more than one million pounds. The highest officially recorded gusts were 116 miles per hour at Bowen between 1 p.m. and 3 p.m. 16th—a record wind velocity for Queensland.

Details of reported damage in the worst affected towns are as follows:—

Ayr—One man killed. One in every three homes severely damaged. Buffalo Hall wrecked, schools and hotels unroofed. Estimated damage £200,000. The Agricultural Research Station at Ayr recorded six hundred and forty-nine miles of wind run in the twenty-four hours to 9 a.m. 17th.

Home Hill—More than one hundred persons homeless. No building escaped damage. Main shopping area a shambles, every window broken. Winds estimated at one hundred miles per hour. Total damage expected to be about £400,000. Seven hundred windmills destroyed in the Ayr-Home Hill area.

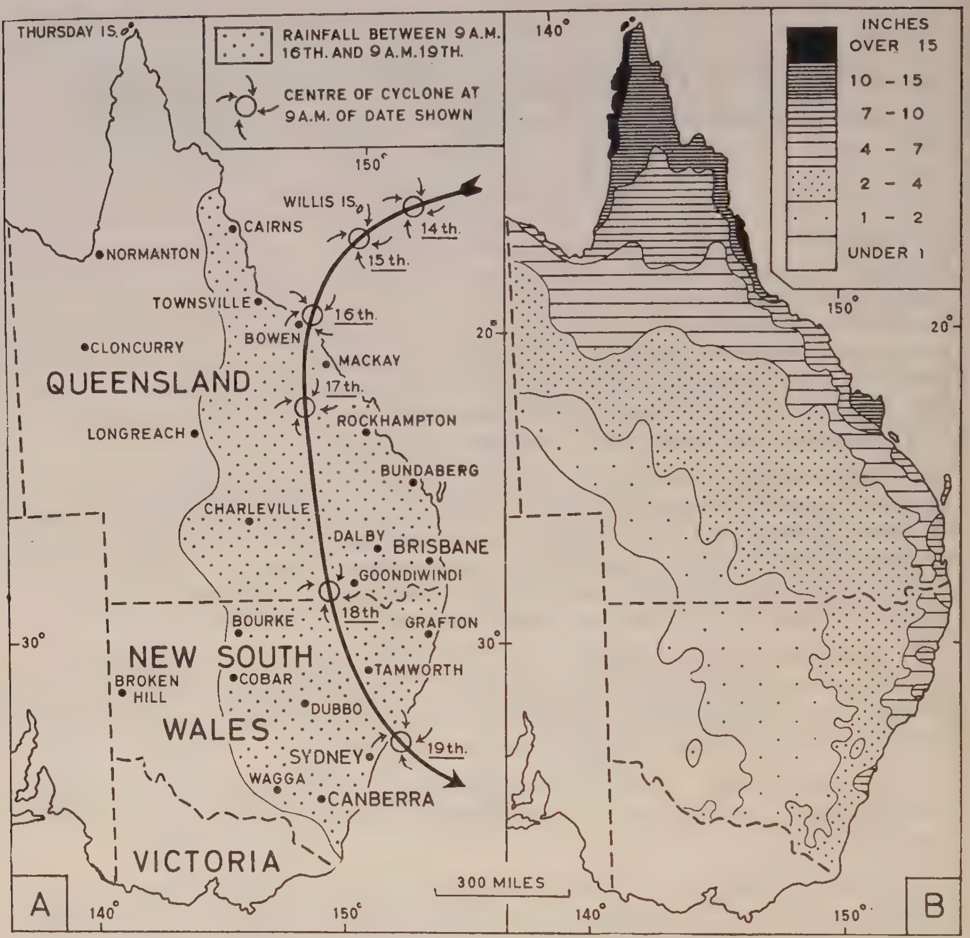

Fig. 1. A. Path and rain influence of cyclone.
B. Average rainfall for February.

Bowen—Forty homes totally destroyed, one hundred and ninety badly damaged, more than three hundred partly wrecked. Severe damage to powerhouse, salt works, coke works and railways. One person injured and dozens of small boats swamped. Latest estimate of damage £600,000.

Proserpine—Fifty houses and hospital badly damaged. Large area of cane flattened. Total damage estimated at £65,000.

Townsville, Mackay, Sarina, St. Lawrence and Rockhampton—Minor damage to homes and power lines.

General damage included widespread disruption to communications and facilities. £25,000 damage to the Townsville Electricity Board's lines was reported and damage to P.M.G. installation was described as the worst in the history of Queensland. Air, rail and road traffic was severely disrupted; cane, fruit and tobacco crops badly damaged along the coast between Giru and Proserpine.

The degenerating cyclone moved rapidly southwards as an intense rain depression on 17th, crossing the inland Fitzroy basin and Western Downs. Widespread flood damage with the destruction of bridges, loss of stock and general disruption of traffic followed in the wake of the rain depression, which passed into New South Wales near Goondiwindi at 9 a.m. 18th.'[1]

During the following twenty-four hours, the rain depression filled rapidly and moved quickly in a south-south-east direction across the north-west slopes of New South Wales and finally passed out to sea in the Sydney-Newcastle area at about 9 a.m. on the 19th. By this time the area of heavy rainfall had contracted greatly and had moved entirely from south-eastern Queensland, where falls were generally less than 0.5 inches during the twenty-four hours ending 9 a.m. on the 19th. During the same period, however, falls of over 1.0 inch were recorded throughout the central-west slopes and the central and southern coastal areas of New South Wales as an easterly stream of very moist air entered into the southern and western sides of the cyclonic circulation of the depression. The rains associated with the storm were not experienced as far south as Victoria, where the weather had been dominated by a ridge of high pressure which extended eastward from an anticyclone centred over the Great Australian Bight.

By 9 a.m. on the 20th, the centre of the depression had moved well out over the Tasman Sea, about 300 miles south of Lord Howe Island. Apart from causing strong westerly winds (up to 25 knots) in Tasmania and southern Victoria, the cyclone had by then ceased to influence Australian weather. Only a few stations reported rainfall, and that rainfall which did occur was in the form of very light and isolated showers. The circulation over the greater part of the continent had by then become anti-cyclonic and dominated by the 'high' which continued to remain almost stationary over the Bight.

It is interesting to note that rainfall over Queensland as a whole during February was generally well below average, and that virtually the only area which received more than average rainfall was that of central and south-eastern Queensland, which lay within approximately 150 miles of the path of the centre of the depression.

The central Queensland coast, and in particular the Bowen-Mackay area, received some of the highest totals for the month in the whole of the state. Throughout most of this area more than 10 inches were recorded during the month, and locally, where orographic influences are pronounced, more than 15 inches were recorded. Most of this total resulted from the heavy falls which accompanied the cyclone on the 16th and 17th. Average rainfall for February along the central Queensland coast ranges between 7 and 15 inches, and tropical cyclones are usually experienced in this area during late summer and early autumn. Hence February 1959 might be regarded as a normal month, apart from the fact that the cyclone was more destructive than usual. The percentage departure from average throughout the central Queensland coastal area ranged between –50 and + 100 per cent (Figs. 1B and 2A and B.)[2]

Southward along the path of the cyclone, and particularly over the Darling Downs and Maranoa districts, the percentage departure from average was considerably higher than in the Bowen-Mackay area, even though the total rainfall for the month was much lower here than along the central coast (Fig. 2A). February 1959 was distinctly abnormal in these areas. Although the average

1. *Weather Review, Queensland,* Commonwealth Bureau of Meteorology, February 1959.
2. Figs. 2A and 2B are compiled from rainfall observations made at 223 stations in Queensland and 259 stations in New South Wales.

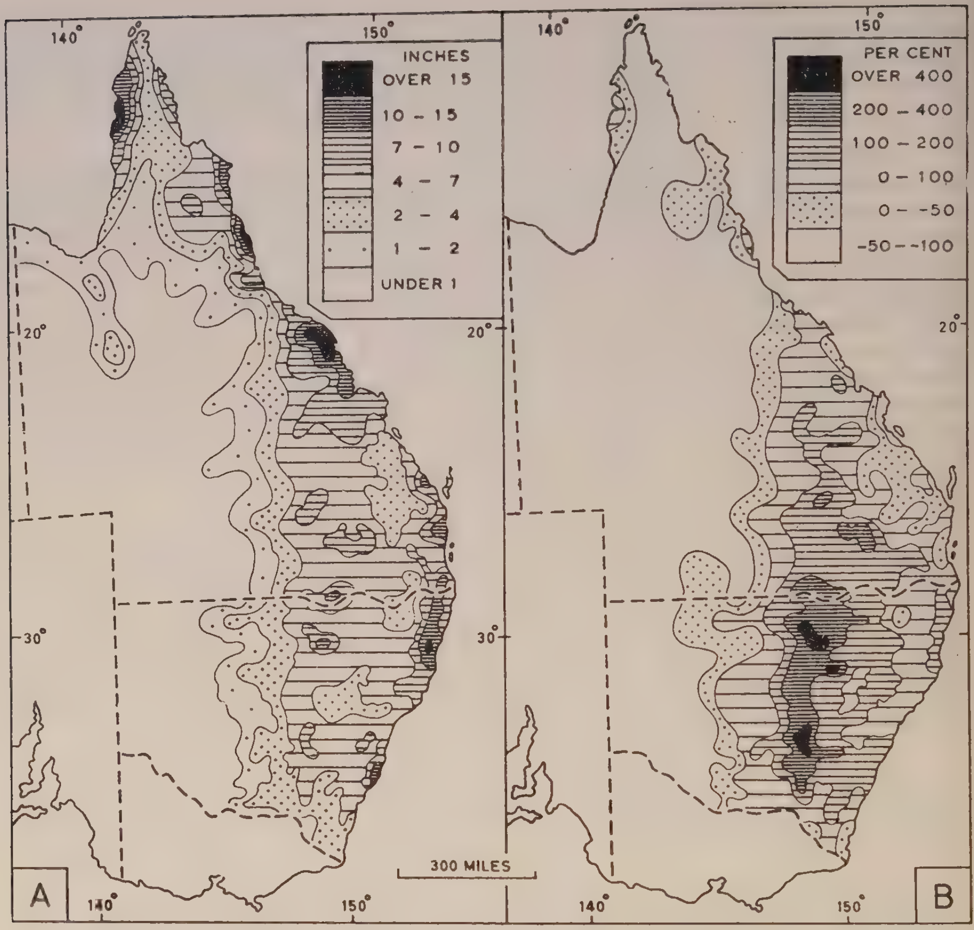

Fig. 2. A. Total rainfall during February 1959.
B. Percentage departure from average.

rainfall for February is only 2 to 4 inches here, the degenerated cyclone produced exceptionally heavy falls during its southward course on the 17th and 18th, thus making the totals recorded through this area generally 100 to 200 per cent above average, and locally up to 400 per cent above average. As shown in Fig. 2B, the percentage departures from average decrease rapidly eastward and westward from the Darling Downs-Maranoa districts, indicating the marked effect of the rain depression of the 17th-18th.

The rains accompanying the degenerated cyclone brought considerable economic benefit to most of central and south-east Queensland. Water catchments were filled, and pastures showed an immediate response sufficient to cause dairy production to rise quickly and an obvious improvement in the condition of cattle. Furthermore, pastures were able to provide a high level of feed for several months as a result of the build-up in sub-soil moisture. Locally some damage to crops was felt, either through strong winds or flooding, but the overall prospect for crops was considerably improved over wide areas. Hardest hit by the storm was

the tall sugar cane within that portion of the coastal area which lay in the direct path of the cyclone. However, further south along the coast the cane crop benefited greatly, as did also the fruit, vegetable and fodder crops. The outlook for summer grain and seed crops on the Darling Downs and Central Highlands was much brighter, and the optimism of agriculturalists was reflected in considerable increases in area planted with grain and seed, peanuts and cotton.

In striking contrast were the unhappy conditions which prevailed in parts of the state which did not receive the benefits of the rain associated with the cyclone. Pastures and stock within the central-west and south-west regions continued to deteriorate. An extensive area west of the Warrego River to the South Australian border, and extending well to the north, remained in the grip of drought, having received only patchy rain earlier in the summer. Hopes for good soaking rain faded as the monsoonal season neared its end, and the spectre of the dry winter ahead grew clearer.

In New South Wales, rainfall in the eastern half of the state was above average for the month, but in western districts it was well below average, as in most parts of Queensland. The above-average rainfall over the eastern half of the state can be attributed to two factors: (1) a prevailing flow of maritime air from the east which resulted from the presence of the anticyclones situated well to the south of the continent, and (2) the passage of the degenerated cyclone across the north-eastern portion of the state on the 18th and 19th. Although positive departures from average are general over a large area of the state, by far the largest of these occur within the area which came under the direct influence of the rain depression of the 18th-19th. Throughout the north-west and central-western plains and slopes of New South Wales, the rainfall for the month generally exceeded the average of 1.5 to 2.0 inches by over 200 per cent. Locally, the percentage departures within this area are extreme, in some cases exceeding 400 per cent.[1]

It is notable that the area of greatest positive departure from average occurs to the west and south-west of the path of the centre of the depression (Figs. 1A and 2B). East and north-east of the storm track the percentage departures are considerably lower, ranging generally from −50 to +100, except along the northern coast of New South Wales where they reach as high as +155 at Grafton. It would appear that this pattern is explicable not only from the fact that the average for the month decreases progressively in a south-westerly direction across the state, but also from the contrasting sources and characteristics of the air entering into the circulation of the weakened cyclone.

Another notable feature resulting largely from the passage of the rain depression is the steep gradient between above-average and below-average rainfall immediately west of the area coming under the rain influence of the storm. This is evident in both Queensland and New South Wales and is quite remarkable in an area where the orographic control of rainfall is so small.

1. Seven stations fall into this category. They are listed below with their percentage departure above average:—

Station	*Percentage Departure*	*Station*	*Percentage Departure*
Pilliga	784	Mungindi	470
Walgett	537	Parkes	454
Grenfell	503	Coonabarabran	410
Forbes	486		

The effects of the heavy rains resulting from the depression were much less impressive in New South Wales than in Queensland. Since most districts in eastern New South Wales had experienced falls well above average earlier during the summer period, water resources had by that time been built up to a comfortable level for both stock and agriculture. These additional heavy falls were therefore largely superfluous and, in fact, more detrimental than beneficial in some instances.

In general, pastures and stock throughout the eastern half of the state were in excellent condition. However, the southern portion of the wheat belt, and the south coastal area in the vicinity of Bega, did not benefit from rains accompanying the cyclone, and the parched aspect of these areas stood in marked contrast to the luxuriant conditions over the remainder of the eastern half of the state. Throughout the entire far west, severe drought conditions comparable to those of south-west Queensland prevailed.

The extent to which the rains resulting from this single tropical cyclone have contributed to the totals for the month in certain areas of Queensland and New South Wales suggests an added element of climatic risk to the agricultural and pastoral economies—particularly within those areas where rainfall is marginal. In a study of rainfall variability in Queensland, Dick attributes the moderate to high variability of eastern coastal areas partly to 'the irregular occurrence of tropical cyclones' and partly to an 'abnormally high incidence of thunderstorms in coastal districts.'[1]

The mid-February cyclone brought a large proportion of its rainfall to areas which are not normally associated with storms of this type. Dick has shown that 'although the values of rainfall variability recorded in the Darling Downs are among the lowest in Queensland, they are none the less substantial, and everywhere higher than the standard world values for places with comparable rainfall totals.[2] From an examination of conditions during February, it would appear that the influence of tropical cyclones upon rainfall variability may be more widespread than is generally appreciated. It is quite probable that no small proportion of the total variability factor in rainfall over a wide area of eastern Queensland and New South Wales is explicable by the erratic behaviour in the frequency and in the movements of tropical cyclones in either their fully-developed, maritime, or degenerated inland forms. The quantitative assessment of the size of this proportion of the total rainfall variability poses an interesting climatological problem awaiting further statistical investigation.

1. Dick, Ross S. 'Variability of Rainfall in Queensland', *Journal of Tropical Geography*, Vol. 11, 1958, p. 35.
2. Dick, op. cit., p. 39.

SOME FORMS OF SHIFTING CULTIVATION IN THE SOUTH-WEST PACIFIC

By R.F. WATTERS

IT IS proposed to examine some aspects of shifting cultivation in the South-West Pacific, and in particular to discuss those forms that originally existed in Samoa and Fiji (Fig. 1) by considering the evidence of early Western observers. It is important to understand in some detail the traditional system by means of which native society had evolved on the whole a rational adjustment to its habitat, especially in view of the great difficulties experienced in introducing Western temperate zone techniques into island groups in the humid tropics. In Fiji the declining production of copra per acre in the last twenty years indicates the necessity for understanding the natural soil processes at work.[1] What is more, since indigenous societies frequently cling more tenaciously to their traditional economy than to some other characteristics of their culture, we must understand all facets of that economy and its place in the culture complex if we are to guide and speed the rate of economic advancement. Moreover, no study of land utilization in the region can be other than superficial if it ignores time depth. Thus studies in historical geography are valuable, and both cross-sectional reconstructions and genetic studies of changing patterns are needed.

Shifting cultivation may be briefly defined as an agricultural system in which land is cropped for a short period and then allowed to lie fallow under natural vegetation for a considerably longer period. It is useful to class as 'bush fallowing' those forms of shifting cultivation in which the fallow period is short (generally less than eight or ten years). Invariably a careful rotation is practised, and higher densities of population are often supported than in other forms of shifting cultivation, although there is a greater danger of a degeneration of the natural vegetation and soil deterioration.[2] Some recent works have rightly stressed the socio-cultural setting in which any form of shifting cultivation exists.[3] Indeed the economy of any society can only be understood fully if seen in the cultural context in which it has evolved, and the nature of the integration and the functional role of agricultural features in the whole culture complex. What is more, in comparing Samoan and Fijian cultivation we must remember that we are making cross cultural comparisons of portions of whole cultures and that reference to the wider cultural setting[4] as well as to environmental distinctiveness is necessary if our approach is to be other than superficial.

1. See A.C.S. Wright and I.T. Twyford, 'Soil Development, Shifting Cultivation, and Permanent Agriculture in the Humid Tropics', *Fijian Agricultural Journal,* Vol. 28, Nos. 3 and 4, pp. 56-61.
2. W.B. Morgan, 'Some Comments on Shifting Cultivation in Africa', *Research Notes,* No. 91, 1957, Department of Geography, Ibadan, Nigeria.
3. H.C. Conklin, 'An Ethnoecological Approach to Shifting Agriculture', *Transactions of the New York Academy of Sciences,* Series II, Vol. 17, No. 2, 1954, pp. 133-42. *Hanuno'o Agriculture, A report on an Integral System of Shifting Cultivation in the Philippines,* F.A.O. Forestry Development Paper No. 12, 1957.
   P. de Schlippe, *Shifting Cultivation in Africa* (London, 1956). K.G. Izokowitz, 'Lamet, Hill Peasants in French Indochina', *Etnologiska Studier,* Vol. 17, 1951.
   J.D. Freeman, *Iban Agriculture* (London, 1955).
4. Ruth Benedict, *Patterns of Culture* (Boston and New York, 1934). See also Melville J. Herskovits, 'Some further comments on Cultural Relativism', *American Anthropologist,* Vol. 60, No. 2, Pt. 1, 1958, pp. 266-73.

In the South-West Pacific, the interaction between culture and environment can be clearly seen in the system of cultivation—the 'contact zone' between the two. What are the major features of shifting cultivation in the region that distinguish it from other tropical regions? Throughout the region shifting cultivation may be classed as an 'integral' system. That is, in Conklin's terminology, shifting cultivation comprised a 'traditional, year-round, community-wide, largely self-contained, and ritually-sanctioned way of life'[1], in contrast to those 'partial' systems in different parts of the world in which permanent field cultivators engage in shifting cultivation to supplement their food supply (termed 'supplementary' sub-type), or where immigrants commence shifting cultivation on moving into an upland area, usually from a permanent field area (termed 'incipient' sub-

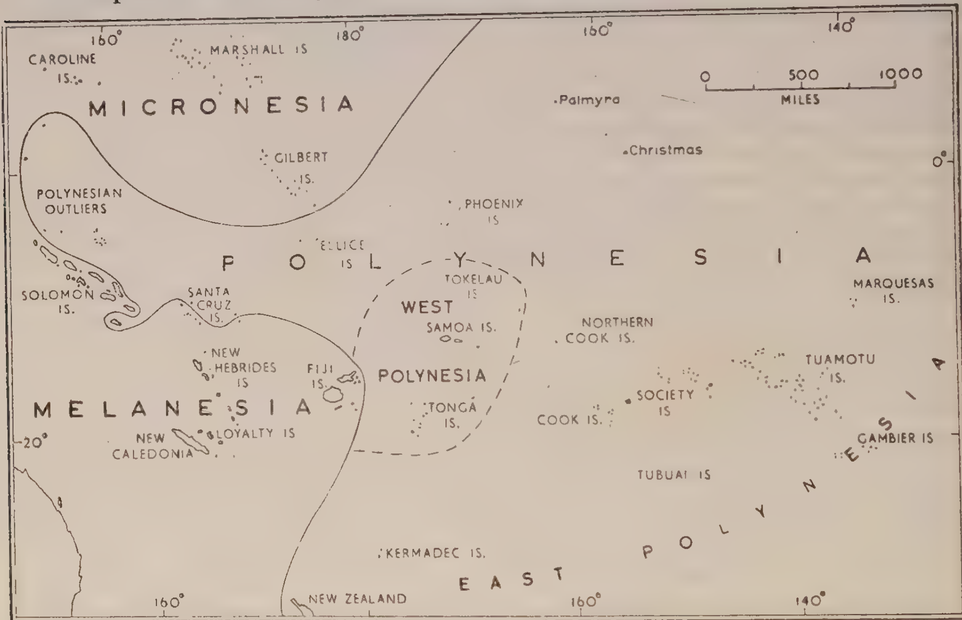

Fig. 1. Oceania, culture and sub-culture areas.

type). In our region two sub-types may be distinguished according to Conklin's classification—'pioneer' and 'established'. Under the first, significant portions of climax vegetation are customarily cleared annually—a practice occurring in parts of New Guinea and, to some extent, in pre-European Samoa. However, the 'established' sub-type was also common; that is, those systems in which tree crops are plentiful and relatively little or no climax vegetation is cleared each year. An unknown number of forms varying between these two sub-types existed in ancient Polynesia and the Melanesian fringe.

Conklin has suggested that at least ten variable conditions must form the basis for distinguishing sub-types of shifting cultivation: (1) principal crops, (2) crop associations and successions, (3) crop-fallow time ratio, (4) dispersal of clearings, (5) use of livestock, (6) tools and techniques, (7) treatment of soil, (8) vegetation cover of land cleared, (9) climatic conditions, (10) soil conditions.

Few would question the importance of recognising the character of each of these variables in any system of shifting cultivation. Climate, vegetation and

1. Conklin, op. cit., pp. 2-3.

soil are the major environmental conditions influencing the cultivator. Principal crops, crop associations and succession, and use of livestock reflect in the main the cultural preferences and traditions of the occupants as well as the environmental possibilities. The crop-fallow time ratio and the dispersal of clearings can be governed by environmental or cultural conditions or by purely random factors, but often reflect populaton density and systems of land tenure. Tools and techniques and treatment of soils are likewise usually influenced by environmental factors, but in the main mark the level of cultural evolution reached, or cultural diffusion of implements, techniques and new concepts. This structural or ethno-ecological approach thus recognises the significance of certain interdependent variables that are frequently determined by various interacting cultural and environmental conditions. To Conklin's list we would add two further variables: the density of population on cultivable land, and the type of settlement pattern. Although these are to some extent dependent upon some of Conklin's variables, their fundamental importance in determining the patterns of occupance and long-term land usage is such that they merit separate treatment. This expanded list of variables will be used to illustrate some forms originally existing in Samoa and Fiji.

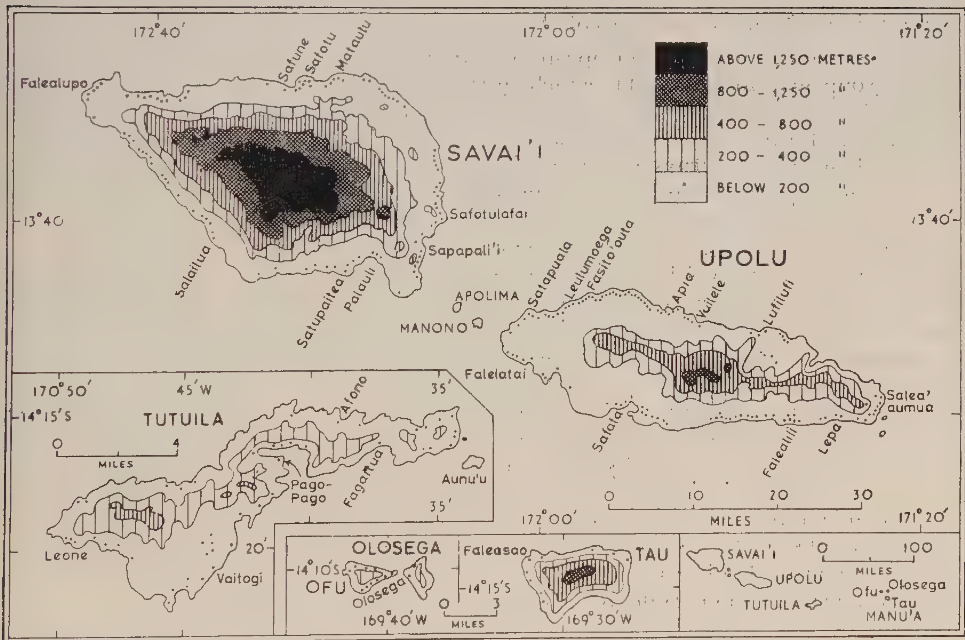

Fig. 2. Samoa, relief and settlement, 1840.

Perhaps the most fundamental distinction that can be drawn between shifting cultivators is between those whose settlements are migratory and those whose settlements are sedentary.[1] In the South-West Pacific settlement was fixed and predominantly coastal in location. The relatively small areal extent of the islands and quite high densities of population, the occurrence of fertile soils on coastal

1. D.F. Cook, 'Milpa Agriculture: A Primitive Agricultural System', *Smithsonian Institution Annual Report* (Washington, 1919), p. 323.
Derwent Whittlesey, 'Shifting Cultivation', *Economic Geography*, Vol. XIII, 1937, pp. 35-52.
Derwent Whittlesey, 'Fixation of Shifting Cultivation', *Economic Geography*, Vol. XIII, 1937, pp. 139-54.

plains, the importance of sea foods in the diet, the ease of communication across the lagoon and the location of coastal springs or river mouths were factors making for sedentary settlement. What is more important, it is probable that the original settlers of Fiji and Polynesia had traditionally lived in that way. This permitted the evolution of a relatively elaborate social organisation and material culture in comparison with those commonly found amongst migratory shifting cultivators.

SAMOA

In Samoa (Fig. 2) as well as Fiji other sources of food were important in addition to the various varieties of taro and yam of the shifting gardens. Wet taro was produced in more or less permanent plots in swamps, and tree crops of coconuts, breadfruit and bananas were important. In Samoa and coastal Fiji, fish was eaten every day in each household, while in mythology, ceremonial and social status, fishing activities were accorded important places. Fowling and gathering played minor roles in the food quest, but supplemented garden produce. This broad economic base reflects a liberal physical environment, which was characterised by abundant sea and forest resources, a generally liberal rainfall, and young or immature latosol soils which still retained medium to abundant supplies of plant nutrients.[1] However, it is clear that tubers from shifting gardens comprised the bulk of the normal diet.

In the immediate pre-European period it would appear that the population of the group was about 80,000[2] which gives a population density of 66 per square mile. The average sized village was probably between 300 and 500. As gardens could be established on slopes as steep as 45° practically all land was cultivable. In normal times an approximate relationship would appear to have existed between the size of population in any village and the total area of arable land within practicable walking distance from the village, the necessary number of years an abandoned garden must lie fallow before recultivation, the number of years a garden could be cropped before it had to be abandoned, and the area of cultivated land required by the average person for the amount of food he ordinarily derived from cultivated plants per year. Recently an attempt has been made to determine by mathematical formulae 'how large a village population can be supported permanently in one locale' given specifiable values for these factors.[3] Although such an attempt is useful up to a point in that it does isolate and show the interplay of the generalised variables involved in the problem, its necessarily rigid formulations can make no allowance for the human variables. Thus the attempt is invalidated by such factors as the difficulty of determining for a whole village over an indefinite period of time what is a 'practicable walking distance', or even what is 'arable land'. At any rate evidence suggests that in the immediate pre-European period land was abundant, utilization very extensive and that after planting adequate food could be gained by a minimum of effort.[4]

1. R.F. Watters, 'The Geography of Samoa about 1840: A Study in Historical Geography', Ph.D. Thesis, University of London, 1956.
2. This figure is derived from la Pérouse's estimate of 1787, and checked by estimating the rate of population decrease in the period of culture contact by working back from the L.M.S Census of 1840 and Wilkes' estimate of 1839.
   Deschanel, *La Politique Française en Océanie* (Paris, 1790), pp. 232-5.
   C. Wilkes, *Narrative of the United States Exploring Expedition* (Philadelphia, 1845), Vol. II, pp. 106-7, 130.
   For a discussion, see R.F. Watters, 'Culture and Environment in Old Samoa', in *Western Pacific: Studies of Man and Environment in the Western Pacific* (Wellington, 1958), p. 45.
3. Robert Carneiro, *Slash and Burn Agriculture: A Closer Look at its Implications for Settlement Pattern.* A paper delivered at the Fifth International Congress of Anthropological and Ethnological Sciences, Philadelphia, September, 1956.
4. R.F. Watters, 'Cultivation in Old Samoa', *Economic Geography*, Vol. 34, No. 4, 1958, pp. 338-51.

Evidence from early Western observers seems to indicate that, on the whole, there were few changes in methods of clearing the land, planting and harvesting, or in the cycle of rotation. Traditional methods as described by observers like Brown and Krämer[1] at the end of the century would appear to be applicable to the pre-European period. It is not known whether any cycle of rotation existed in densely populated areas, but since a more or less haphazard rotation was followed in modern Tutuila where the population pressure was at least as great,[2] it does not appear to have been probable. Moreover, Mead has attested that in the relatively densely populated Manu'a group in the nineteen twenties land was regarded as a 'never-failing, inexhaustible gift of the Gods'[3]. Convenience seems to have been a major factor in determining which piece of forest was to be burned. At the end of the rainy season, when family heads (*matais*) had made their choice, the largest trees would be ring-barked, some hacked down with stone adzes and then the strip burned. Brown and Setchell have noted that some trees would be left for future building purposes or firewood, and others would withstand the fire.[4] A minimal condition for reclearing appears to have been land on which saplings were only as thick as a man's arm. However, a long fallow period is probable over most areas of Upolu and Savai'i.

In spite of natural hazards, food requirements were obtained so easily that methods of cultivation were careless. The only tools used in cultivation were the digging and planting sticks. The spacing of taro and yams was usually near the optimum distance, but care was not always taken to keep taro holes open, or to protect the garden from the ravages of wild pigs. Only one or two weedings appear to have been usual. After two years of cultivation, or perhaps as many as three crops, it was no longer economic to continue cultivation in the face of increasing weeds and declining soil fertility.

It is impossible to determine the pattern of dispersal of gardens. As villages usually had a narrow strip of land running from seashore to mountain top, a section of each forest zone from strand vegetation to mossy or even elfin forest was available. In modern Tutuila gardeners walk up to distances of four miles or more from their villages.[5] Temporary shelters would be built on distant gardens but there is no evidence of satellite villages being built near the gardens —a development occurring in parts of Western Samoa to-day. However, at least 42 inland villages existed in the immediate pre-European period, many along the Falelatai trail.[6] Krämer reported taro gardens on the crest of the mountain range behind Apia.[7] On such unstable steep land soils, the operation of soil creep meant that the fertility of the soil would be continually renewed—a factor that more than compensated for the higher acidity and more rapid leaching of soils in areas of high rainfall.

No livestock were kept on the gardens, although domestic pigs and fowls roamed around the villages. Garden soil was not treated at all, and there does

1. G. Brown, *Melanesians and Polynesians* (London, 1910); A. Krämer, *Die Samoa — Inseln* (Stuttgart, 1902), 2 Vols.
2. J. Wesley Coulter, 'Land Utilisation in American Samoa', *Bishop Museum Bulletin,* No. CLXX, 1941, pp. 23-9.
3. M. Mead, 'The Social Organization of the Manu'a', *Bishop Museum Bulletin,* LXXVI, 1930, p. 45.
4. Brown, op. cit., p. 131.
   W.A. Setchell, 'American Samoa', in *Carnegie Institute Washington Publication,* 1924, p. 19.
5. Coulter, op. cit., pp. 23, 26, 29.
6. R.F. Watters, 'Settlement in Old Samoa', *New Zealand Geographer,* Vol. 14, No. 1, 1958, p. 6.
7. Krämer, op. cit., Vol. 2, p. 136.

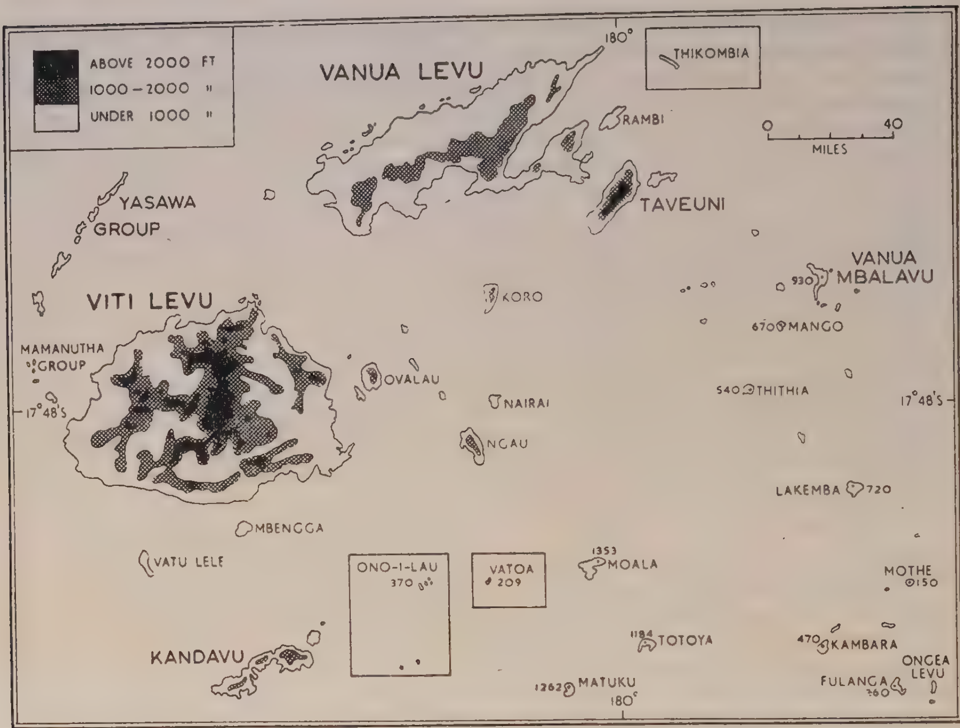

Fig. 3. Fiji, topography.

not appear to be any evidence of utilization of the fallow period by planting useful trees when the garden was abandoned.

Burning, repeated cultivation or insufficient length of the fallow period do not appear on the whole to have radically disturbed natural environmental conditions in Old Samoa, despite the fact that much of the vegetation of lowland and middle elevations is considered by a recent observer to be secondary forest.[1] The short, coarse grass of the *tula* areas of the once fortified coastal hills of Laulii, Luatuanu'u and Tiavea, however, results from repeated clearing and burning to keep open a wide field of view.[2] Unlike the Tongans, Niueans and Fijians, the Samoans have always been noted for the limited amount of burning in land clearance.

Thus cultivation was particularly extensive even for a form of shifting cultivation. The static character of agricultural techniques seems to indicate a bountiful physical environment that may have inhibited evolution in some levels of culture.

FIJI

In the Fijian group (Fig. 3) insufficient evidence exists to indicate many variant forms of shifting cultivation. This description then is mainly general. Most accounts of Fijian agriculture refer to coastal Viti Levu and Vanua Levu

1. T.S. Thompson, 'The Territory of Western Samoa', *Empire Forestry Review*, Vol. 32, No. 4, 1953, p. 312.
2. A.C.S. Wright, Personal communication, 19th July, 1957.

Photo: R.F. Watters

Plate 1
Nalotawa, in the dry zone of Viti Levu, Fiji. The predominance of bare hills of reeds and grasses testify to the effects of burning.

Plate 2
Gardens on unstable hillside soils behind a banana plantation, Aana, Western Samoa.
Photo: R.F. Watters

Photo: Rob Wright
Fiji Public Relations Officer

Plate 3

Fulanga Lagoon, Lau Group.

in which the Polynesian influence varies somewhat, while the Highlands of Viti Levu are distinctive in many ways. Environmental as well as cultural conditions are far from uniform. The co-existence of continental and oceanic rocks, the great variation in age and structure of rock formations, the variety of climatic conditions and the range of soil types differing widely in stage of development and degree of leaching, together produce varied local environments which are also reflected in forms of cultivation.

On the whole, in comparison with Samoa, it is true to say that a greater adaptation to the habitat has occurred in many parts of Fiji in methods of cultivation. In addition to this environmental response, cultural diffusion, or the interaction of cultural phenomena, presumably explain the existence of a primitive form of terracing, a method of irrigation by means of pipes made of hollow tree ferns, and the practice of planting food crops in a triangular pattern to minimize soil movement.

Differences from shifting cultivation in Samoa are also related to the distinctive social organization. In Samoa, gardens were either the product of village effort, in which unrelated households (each directed by its own family head, or *matai*) combined in the operation, or they were cleared and cultivated by the households for their own use. In Fiji, ownership of land lay with broad patrilineal kin groups, although variations existed in the width of the social unit holding the land. Thus in many villages the *matangaali* or community of family groups within the broader federation or *yavusa,* owned the land. In other parts a smaller social unit, the extended family or *itokatoka* had evolved land holding rights within the framework of the overall landowning group.[1] If the population density in any area was light, it would seem that the land holding rights of small social units tended to crystallize out much more clearly than in densely populated areas.[2]

In modern times both heads of households and individuals chose land for garden sites.[3] Each household would have a few gardens or plots, each a few square chains in area. Horne, in 1878, declared that the native selected land best suited for the various crops. At a time of little population pressure, a garden site could be five or six miles from the village.[4] As in Samoa, huts would be built near distant gardens. The natives recognised many soil differences, and a good number of soil types were differentiated on the basis of colour and texture. Field work to-day suggests that the actual choice of garden sites was made on the basis of landscape features that escaped the notice of several perceptive early observers. Nayacakalou found that in a traditional village well up the Wainimala River, land would only be selected for clearing if the growth was 'thick enough', while in a village on the Rewa delta clearings in small patches of forest were preferred for garden sites.[5]

Clearing was done by sharpened hardwood clubs made of *vesi* (Intsia bijuga); in the province of Nandronga stone axes were also used.[6] The clearing

1. R.R. Nayacakalou, *Tradition, Choice and Change in the Fijian Economy,* M.A. Thesis, Auckland University College, 1955, p. vi.
2. Ibid., pp. 199-202.
3. Ibid., p. 202.
4. J. Horne, *A Year in Fiji* (London, 1887), pp. 78-9, 74.
   M. Echardt, 'Uber den Landbau der Viti-Insulaner', *Globus,* Vol. 41, 1882, pp. 233-6.
5. Nayacakalou, op. cit., pp. 202, 240.
6. L.W. Harwood, 'Observations on Indigenous Systems of Agriculture', *Fijian Agricultural Journal,* Vol. 21, Nos. 1-2, 1950, p. 4.

and planting of yam gardens required careful organization, and the chief, with the advice of the elders, directed all the activities of the clan. In comparison with Samoan practice, more clearing appears to have been done by hand than by fire, at least in areas in which the forest cover was not dense.[1] Burning was used in particular to consume piles of debris. In Taveuni and many islands of the Lomaiviti group in the windward areas, the wetter vegetation was not burned in clearing the land. A successive clearance of bush each year in parts of western Viti Levu to grow yanggona (kava) is also distinctive—gardens advance progressively into the bush in a straight line.

The Fijian year was divided into eleven months, depending on the flowering times of certain trees and the various stages of cultivation of the principal crop, the yam.[2] With long digging sticks, circles two feet in diameter were dug and then mounds built about two feet high and four or five feet apart. Women followed with short sticks to break up clods and then pulverize the earth with their hands. In August the yams were planted and in September reeds were set in to support the yam stalks. A hoe, made of tortoise shell or oyster shell, was occasionally used for weeding[3]—an implement that did not exist in Samoan material culture. In February and March the yams were harvested and stored in small sheds, and in May the irrigated terraces were planted with *dalo* (taro).

In many details of cultivation, the Fijian showed a remarkable appreciation of environmental conditions. He was well aware of the poor fertility of deforested soils, where colloidal transformation and advanced laterization existed.[4] It is probable that terracing was evolved or adopted because of the knowledge that the unstable steep-land soils would produce crops for two or three years instead of only one year on the stable grassy plains, and that in addition the fallow period on steep-land soils could be shorter. It has been suggested that the primary function of the bamboo palisade terraces may have been to secure an even distribution of water over the slope.[5] To check the washing of fertile topsoil down to the bottom of slopes, ditches were often dug across the garden. Quain reports an instance of the planting of the best seed yams at the bottom of a slope where the soil was deepest, while inferior halved or quartered seed yams were planted in the thin soil at the top.[6]. In parts at least, considerable attention was given to the provision of an adequate cover for the soil surface. Intercultivation was frequently practised and Horne reports that a few trees with large crowns were sometimes left to minimize evaporation. The value of manure was recognized to some extent, as it was used on favourite varieties of sugar cane,[7] although not on other crops. The fallow land was utilized to some extent, as bananas were frequently planted at the close of the cropping period after harvests of yam and *dalo*. This may be due to the importance of the banana in the hilly interior, where coconut palms were rare. In modern times coconut palms are often planted in coastal gardens prior to abandonment. Supernatural sanctions played their part

1. B. Quain, *Fijian Village* (Illinois, 1948), p. 128.
   Horne, op. cit., p. 75.
   B. Thomson, *The Fijians: A Study of the Decay of Custom* (London, 1908), p. 339.
2. B. Seeman, *Viti: An Account of a Government Mission to the Vitian or Fijian Islands in the Years 1860-61* (Cambridge, 1862).
   D. Hazelwood, *Fijian and English Dictionary* (Vewa, 1850), p. 180.
   Harwood, op. cit., pp. 57-8.
3. Horne, op. cit., p. 80.
4. Wright and Twyford, op. cit., pp. 57-8.
5. Ibid., p. 59.
6. Quain, op. cit., p. 130.
7. Horne, op. cit., p. 78.

as they did in Samoa, and occasionally certain plants were grown at the edge of gardens to ward off malignant spirits. There appear to have been limits to the toleration of a gardener's laziness, and no self-respecting Fijian would run the risk of social disapproval. Moreover the fertility of the garden was considered to depend on a man's rapport with his ancestors as well as his zeal for gardening, and both reflected his ambition.[1]

No evidence appears to exist as to the length of the fallow period in different areas. In spite of the various methods that have been noted, by which the Fijian adjusted his economy to his environment, the extensive deforested *talasinga* landscape of modern Fiji convincingly proves the contention that the Fijian has not lived in perfect harmony with his habitat, at least not in the era of culture-contact. While the depredations of the sandalwood traders took a heavy toll of some forest areas, and the impact of a cash economy has had deleterious effects on land utilization in some parts, the testimony of Horne in 1878 seems to be substantially correct. He declared that: 'It is apparent that, with a dense population to support, and the annual requirement of new land whereon to grow food crops, if this system of agriculture be not abolished it will bring ruin to the whole country.'[2]

In the middle of the century, according to the estimate of Erskine (whose information came from the missionaries), the population of Fiji was between 200,000 and 300,000,[3] which means a density between 28 and 43 per square mile. Since far greater areas of stable, senile soils occur on the older low-lying rock formations of Fiji than can be found in Samoa, a far lower proportion of the land is valuable for crop production. The long periods of drought on the leeward side of the main islands had led to the establishment of grasslands before contact with the West occurred, and even in windward areas at the time of Horne's visit considerable deflection from the natural succession had occurred. In areas in which population pressure resulted in inadequate fallowing or repeated burning, declining soil fertility was reflected in the growing ascendency of plant species that were tolerant of low nutrient supply, extremes of drought and moisture, and tending towards greater inflammability. An inferior layer of acidic litter was produced, intensifying the leaching process and leading to a deterioration in the organic cycle.[4] Frequent firing of such vegetation led by successive stages to the dominance of grass and ferns. It has been pointed out by Harwood that the province of Mathuata in the dry zone of Vanua Levu was described by Seemann in 1860 as the most productive in the group. Many areas of this province (whose name means 'surplus of crops') are to-day greatly impoverished, due to the increase in population, over cropping of cash crops and a decline in traditional control over methods of cultivation.[5]

LAU

Our last example of forms of shifting cultivation comes from the Lau islands of the Fiji group, which lie some 200 miles east of Viti Levu, and extend over

1. Quain, op. cit., p. 127.
2. Horne, op. cit., p. 80.
3. J. Erskine, *Journal of a Cruise Among Islands of the Western Pacific, in H.M.S. Havannah* (London, 1853), p. 235.
4. Wright and Twyford, op. cit., p. 57.
5. Harwood, op. cit., p. 7.
For other accounts of Fijian agricultural practices, see L.W. Harwood, 'Native Food Crops of Fiji', *Fijian Agricultural Journal,* Vol. 9, Nos. 2 and 3, 1938, pp. 8-11, 6. Also, W.L. Parham, 'The Fijians as Agriculturists', *Fijian Agricultural Journal,* Vol. 8, No. 3, 1937, pp. 15-17.

four and a half degrees of latitude. The group of over sixty islands, comprises only 178.4 square miles, of which one-third is in three islands, Moala, Lakemba and Vanua Mbalavu (Fig. 3). Examples from this group provide to some extent a transition between the forms considered in Samoa and Fiji, for the Lau Islands are the meeting point of Polynesia and Melanesia. What is more, the group provides a geographical laboratory for the study of the interaction of culture and environment; the small areal extent of a wide variety of local habitats focusses the relationship. The transition from continental to oceanic rocks is associated with an increasing sparseness of forms of flora and fauna as one moves eastwards from the main islands of the Fijian group. In particular, all islands may be classified into one of three groups—volcanic, coral, or a combination of the two.

On the coral atolls and part-raised atolls, the natives did not cultivate the land until the introduction of manioc and sweet potatoes in recent times, subsisting merely on gathering, fowling and fishing.[1] The mineral deficiencies and shallow depth of calcareous soils were a minor disadvantage in comparison with the relatively low and uncertain rainfall. While in normal years most households have sufficient garden food, on some coral islands natives depend more on gathering than gardening,[2] and some abandon clearings through lack of energy or fear of evil spirits in the neighbourhood. Old people on Kambara claimed that the sweet yam (*kawai*) was there before the Tongan conquest but that gardening began with the coming of the Tongans.[3] Although traditional evidence is suspect, it is quite feasible that techniques of cultivation on this island at least were introduced by the Tongans, as many other items of their culture have been adopted. Since much of Tongan agriculture was adapted to the habitats of small coral islands as well as to 'high' (volcanic) islands, their techniques would have been particularly applicable to Lau. Contrasts in land utilization in the islands that practised gardening may be illustrated by considering Lakemba in the nineteen thirties with its big yam fields containing thousands of mounds, and Mbau, in which a field was considered large if it contained only 300 yams.

Throughout Lau, land is divided into three classes: garden land, village land and the bush.[4] On one representative island the land is divided into sections, running from the beach to the centre of the island. The hamlet, comprising the clan, was the land-owning unit, and the headman of the clan controlled the clan lands, which were divided between sub-clans and frequently between families. Hamlets were situated inland until the coming of Christianity.

The pressure of population in Lau and the uncertain rainfall led to an early deflection in the succession of the natural vegetation. Thus Erskine in the mid-nineteenth century reported that Lakemba was not very thickly wooded. The population of about 800, representing about sixty persons to the square mile, cultivated irrigated taro on the coastal plain and in ditches surrounding fortified villages — in addition, presumably, to shifting patches on the hills.[5] As population was then declining, it is certain that the pressure on the land was greater in the pre-European period. Although yams were the main crop, huge taro fields extended

1. L. Thompson, 'Southern Lau', *Bishop Museum Bulletin,* Vol. CLXII, 1940, p. 10.
2. L. Thompson, *Fijian Frontier* (New York, 1940), p. 83.
3. Thompson, 'Southern Lau', p. 147.
4. Thompson, *Fijian Frontier,* p. 76.
5. Erskine, op. cit., pp. 170-1.

over much of the island until early in this century.[1] The landscape of Lakemba has long been denuded of forest vegetation, and only odd trees of casuarina or screw pine (*Pandanus*) dot the red slopes of bracken and grass.

Clearing land for planting is an easy task on such land. From April to June the reeds of the selected fallow land were cut and beaten down, and the rubbish burnt after a firebreak had been cut. On the rare occasions when new land was cleared, a flat area was selected and fires were lit around tree trunks. However, Thompson reports tree trunks still standing after fifteen years.[2] This seems to suggest that Lauan agriculture was adapted to bracken, reed-covered land, and that their techniques for clearing forest may have been inferior. This view appears to be supported by Thompson's reference to the occasional abandonment of cleared land because of the vigorous regeneration of shrubs and bushes. After the yam patches were dug, old men followed the diggers to break up the clods and heap up mounds. Yam planting was done mainly in July and August, although it frequently extended to November. A Tongan method was commonly used in planting: a deep narrow pit was dug, the surface soil grubbed into the hole, then the top soil put in and finally the earth from the bottom heaped on top.[3] All clans combined to plant the field of the highest chief on Lakemba; nobles had their fields planted by dependent villagers. Dry spots were preferred as sites for yam gardens, and reeds were needed to support the growing stalks. In January or February first fruits were ceremonially offered to the chiefs. After harvest in March and April the yams were stored in small huts near the gardens according to the Fijian custom. Although the notion of rotating crops rather than land is a European concept, the Lakembans have for a long time often followed a crop of yams with sweet potatoes, bananas or some other crop. In modern Lakemba, occasional inter-cultivation of yams and bananas was practised.

Taro planting again illustrated the combination of Tongan and Fijian culture traits, two distinctive methods being formerly in use. In the Tongan method, conical shaped pits four feet deep were dug, while in the simpler Fijian method (the only one still practised) the taro was planted in holes filled with rubbish.[4]

The presence of fine forests of hardwood on Kambara may delude the casual observer into concluding that the Lau group is favoured in the quality of its habitat. Evidence is lacking on the length of the fallow period and the dispersal of gardens in relation to the settlement pattern, but the bare landscapes and small area of most islands suggest that burning may have frequently got out of hand or that inadequate time was allowed for regeneration before cropping was renewed. What is more, destruction of gardens in war time was a very real hazard, as in coastal Fiji.[5] Even in the larger islands, pockets of arable soil are scarce and shallow, and volcanic outcrops on Kambara provide only a very limited area. Of the three so-called 'famine' isles of Kambara, Fulanga and Ongea, Fulanga has the least soil. On this point, Thompson writes: 'The natives say this is because the first inhabitant of Fulanga was a hen. She had some chicks and when the chicks were hungry she said: "Why don't you scratch?" So they scratched and scratched and finally they scratched the bottom out of the

1. A.M. Hocart, 'Lau Islands, Fiji', *Bishop Museum Bulletin,* No. LXII, 1929, p. 107.
2. Thompson, 'Southern Lau', p. 142.
3. Hocart, op. cit., p. 104.
4. Ibid., p. 107.
5. Erskine, op. cit., p. 284.

land. The chicks are the people of Fulanga and the jagged pock-marked island is called Vanua Sea or scratched land.'[1]

CONCLUSION

In the three examples chosen many similarities existed in the character of shifting cultivation. However, certain differences are apparent, some of which are most significant. These are all the more striking when it is remembered that culture contact and trading occurred between Samoa, Fiji and Lau in the pre-European period. Shifting cultivation in old Samoa appears to have been more extensive than in Fiji and, in most parts, land appears to have been rotated at will. While many Fijian elements were woven into the total web of Samoan life, it is significant that the practices of irrigation and terracing were not adopted. It appears that Samoan culture and habitat provided little challenge to the occupants to accept innovations, and an economy differing little, in all probability, from that of the Proto-Polynesians was sufficiently satisfying to inhibit evolution of land utilization techniques.[2] The development of a self sufficient self view and world view would have been possible only if methods of land utilization produced no marked deterioration in the quality of the habitat. Migration of surplus population presumably occurred before this stage was reached, and thus to the Samoan land always seemed to be available. The Samoan climate permitted rapid regeneration of the natural vegetation, and burning was strictly limited. In the absence of crops that could be used in a permanent or semi-permanent rotation, the form of shifting cultivation was entirely rational, and since society possessed the required mechanisms for dealing with over-population, there was no need to adopt techniques of more intensive cultivation. In the era of Western penetration, when traditional methods of population control no longer existed, there seems to have evolved a trend towards a rotational bush fallow, systematic successions of different crops, inter-cultivation, and even some semi-permanent forms of agriculture.

In Lau both climate and soil type were less favourable, but so liberal were the supplies of sea food and forest products that gathering and fishing remained very real alternatives to gardening. This environmental response appears to have inhibited the evolution of agricultural practices. Even on the larger 'famine isles' there was no cultivation of taro in humus pits — a technique commonly practised on coral atolls.[3] Society and habitat did not exist in a relatively stable equilibrium as in Samoa, and the rapid aging of the soils and speedy decline in the natural nutrient-supplying mechanisms led to a steady deterioration in the habitat that was evident even in the early years of culture-contact. Environmental change meant however a distinctive evolution in technique: in Lau, digging-stick procedures were adapted to bracken and grasslands.

In Fiji, shifting cultivation was more closely adapted to environmental conditions, and climatic variations throughout the group are reflected in different planting times, variations in polycultural practices and minor local refinements of techniques. The high level of plant metabolism and the inadequate supply of water in many seasons, meant that the plant and soil systems were under a

1. Thompson, *Fijian Frontier*, p. 4.
2. Watters, 'Culture and Environment in Old Samoa'.
3. J. Barrau, *Polynesian and Micronesian Subsistence Agriculture* (South Pacific Commission, Noumea, 1956).
   J. Barrau, *Subsistence Agriculture in Melanesia* (South Pacific Commission, Noumea, 1955).
   E. Massal and J. Barrau, 'Food Plants of the South Sea Islands', *South Pacific Commission Technical Paper*, No. 94, Noumea, September, 1956.

measure of tension,[1] which could lead to rapid changes in soil structure and composition when the forest cover was cleared. The dangers of shifting cultivation in Fiji thus appear for environmental reasons to be rather greater than in Samoa, but above all, the failure of native society to control burning activities with great care led to disastrous consequences. In the illuminating record of the botanist, Horne, we can witness the tragic revolution in environment.[2] Although recent students of the problem in Fiji have declared that shifting cultivation is 'still not a bad way to grow essential food crops' provided there is still ample steep land available[3], it appears that shifting cultivation failed to conserve natural resources on the stable lowland soils and in dry areas as a direct result of the breakdown of an efficient organic cycle.

Insofar as the region considered here is concerned, the author would like to take a position midway between that of Gourou[4] and Morgan.[5] To some extent, shifting cultivation was adapted to tropical conditions (Gourou's thesis) and in Samoa it was in harmony with soil conditions. However, Morgan's more precise thesis — that shifting cultivation represents an adaptation only in the choice of crops and the methods by which it is applied — receives confirmation in details of Fijian methods. Demangeon's view that inferior techniques and low population densities explain shifting cultivation[6] cannot be supported: population densities were frequently quite high, while the digging-stick was admirable for making holes and levering up roots. The only interpretation that is satisfactory is one which recognises the function of several variables: tropical environments, cultural appraisals, levels of technology, and population densities.

It must be emphasised that the future of permanent agriculture in the humid tropics lies largely in solving problems of utilization and conservation of the stable but poor soils of the lowlands.[7] Until this agricultural problem is fully solved in all territories, much merit would appear to lie in one line of approach which concentrated on improving aspects of shifting agriculture in relatively underdeveloped steep land areas. Suggestions that have been made include the planting of useful tree crops during the fallow period, the introduction of superior varieties of aroids in the place of traditional species or forms, and the introduction of legumes and green manures into the crop cycle or fallow. Other proposals include artificial soil fertilization (compost, ashes and chemical fertilizers), increased mulching, inter-cultivation and the establishment of windbreaks to reduce evaporation and to protect the soil, and the introduction into the traditional crop cycle of cash crops for export and the local market.[8]

Geographers who advocate an early and complete abandonment of traditional agricultural systems should realise that these systems are involved in a central position in the process of acculturation and that changes in agriculture so urgently needed will produce a powerful ripple effect throughout all spheres of culture,

1. Wright and Twyford, op. cit., p. 57.
2. Horne, op. cit., pp. 7, 16-17, 20, 23, 30, 37, 39, 40, 44, 49-50, 61-3, 68-70, 132-4.
3. Wright and Twyford, op. cit., p. 59, and Harwood, 'Observations on Indigenous Systems of Agriculture', pp. 4-6.
4. P. Gourou, *The Tropical World* (London, 1953), pp. 31-2. Also, Lord Hailey, *An African Survey* (London, 1957), p. 819.
5. Morgan, op. cit.
6. A. Demangeon, *Problèmes de Géographie Humaine* (Paris, 1947), p. 179.
7. Wright and Twyford, op. cit., pp. 60-1.
8. Barrau, 'Polynesian and Micronesian Subsistence Agriculture'.

affecting and perhaps transforming much of the social organization,[1] value system and many traditional behaviour patterns. While such widespread repercussions may be beneficial in the long run in the removal of cultural disincentives to a rapid increase in production and an improvement in techniques of conservation, it would be well if a policy could be pursued that would lead to rapid but harmonious change and avoid cultural disintegration and social chaos. This suggestion does not advocate a slow rate of change, but rather a policy of development that is well aware of what the effects of change are likely to be not only in the economy and in the environment, but also in all spheres of culture.

1. For an example of this, see M. Sahlins, 'Land Use and the Extended Family in Moala, Fiji', *American Anthropologist*, Vol. 59, No. 3, 1957.

POPULATION AND LAND UTILIZATION IN THE ASSAM VALLEY

By TOR FR. RASMUSSEN

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INTRODUCTION

AFTER Independence in 1947 the political map of India was completely changed. Two new republics were established. The former princely states were persuaded to join India or Pakistan, and the Indian Republic was organized into the so-called Part A, Part B and Part C States. In 1956 the state boundaries were reorganized, and the political map of India today consists of 14 states (including Jammu and Kashmir) and some smaller areas which are centrally administered.

Assam State is the only state which did not have its borders changed by the state reorganization in 1956. Assam is squeezed in between Tibet, China, Burma and East Pakistan with only a small outlet along the foothills of the Himalayas to West Bengal (Fig. 1). Due to its location as an appendage in the north-eastern corner of India, surrounded by high mountain ranges and international borders on three sides, Assam State may be regarded as a political and geographical unit.

Geographical Divisions

The State area consists of three major types of geographical landscape, each belonging to one of the familiar structural macro-divisions of India. Due to historical traditions and cultural characteristics these regions are also administrative divisions. The two territories, Manipur and Tripura, former Prince States, are now centrally administered.

(1) *The Plains Districts.* These cover a little more than one fourth of Assam, and are by far the most important part of the state as the majority of the population lives here. Six of these districts are situated along the Brahmaputra, namely, Goalpara, Kamrup, Darrang, Nowgong, Sibsagar and Lakhimpur, while Cachar is situated on the upper banks of the Surma River (Fig. 1).

The plains area of Assam may be regarded as an extension of the Indo-Gangetic trough, the land having been built up of alluvial clay with sand and gravel. The mighty Brahmaputra River with its tributaries gives life to the landscape. Brahmaputra's low water level at Dhubri in western Assam, about 400 kilometers (260 miles) from the sea, is not more than about 24 meters (78 feet) above sea level. At Dibrugarh, in Upper Assam about 1,000 kilometers (600 miles) from the sea, the low water level of the river is about 101 meters (332 feet). At the confluence of the Dihang, Dibang and Luhiti rivers, in the north-east, the altitude is about 121 meters (370 feet) above sea level. The district boundaries mainly follow the distinct border between the plains and the hills, so that the plains districts are almost completely situated on the alluvial deposits.

Mountains and jungle separate Cachar from the plains along the Brahmaputra. Prior to the Partition this part of Assam had its natural economic contacts westward through the Surma Valley to East Bengal. However, it was the Hindu religious,

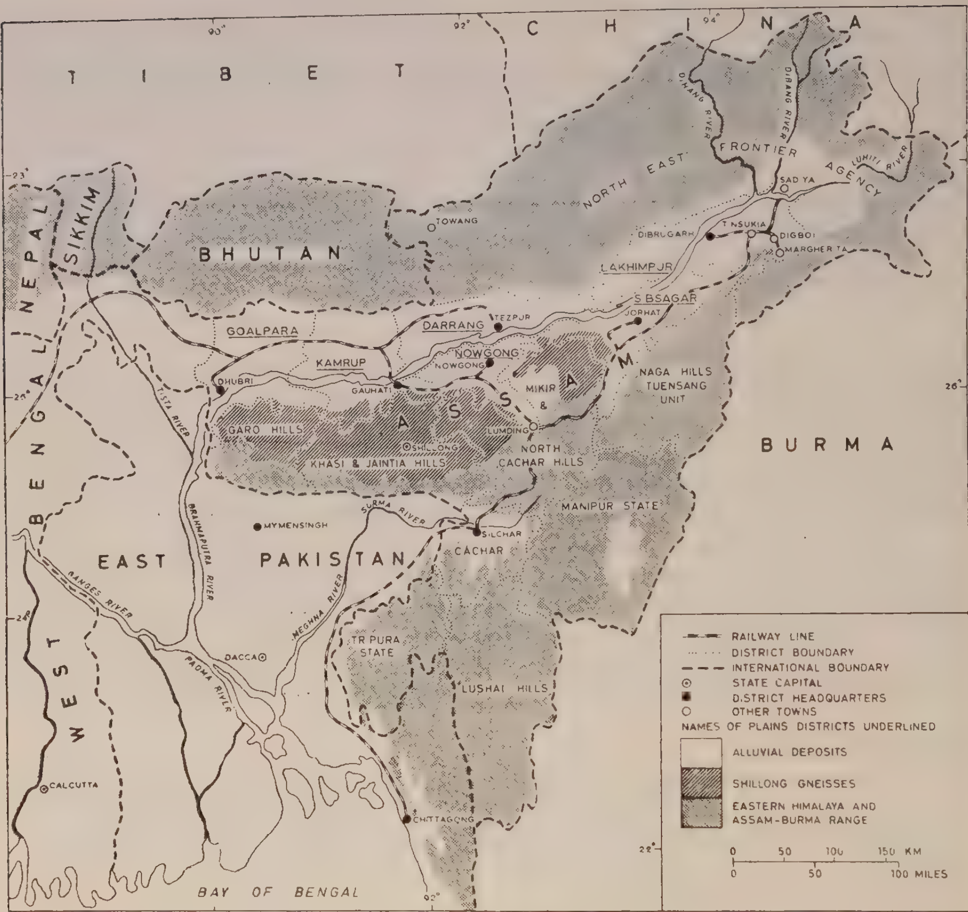

Fig. 1. Map of Assam, showing administrative divisions, railway lines and main geological features.

TABLE 1: AREA AND POPULATION OF ASSAM, 1951

	Sq. kilometers	Sq. miles	Population
Assam Valley	52,682	20,341	6,690,000
Cachar	6,972	2,692	1,116,000
The Plains Districts	59,654	23,033	7,806,000
The Hill Districts	58,880	22,734	967,000
N.E.F.A.	85,246	32,914	*
Naga Hills — Tuensang Unit	16,396	6,331	*
Assam State	220,176	85,012	*
Manipur State	22,346	8,628	578,000
Tripura State	10,443	4,032	639,000

*N.E.F.A. and Naga Hills-Tuensang Unit have never had a thorough population census.

cultural and social background of the people in Cachar which made them decide in 1947 to stay with India. This decision has caused them serious economic difficulties, not only because of the refugees coming from East Bengal, but also because the trade route through the Surma Valley was closed, so that the economic life of this area had to adapt itself completely to an outlet along the railway to the Assam Valley.

The term *Assam Valley* will be used for the plains area along the Brahmaputra because it is assumed that the name was derived from the Ahoms who ruled mainly on the plains of the Brahmaputra up to about 1800. The term *Brahmaputra Valley* applies to the plains and the mountain slopes. This study will deal mainly with the plains districts.

(2) *North East Frontier Agency (N.E.F.A.) and Naga Hills — Tuensang Unit.* The North East Frontier Agency and Naga Hills — Tuensang Unit surround the Assam Valley to the north and the east. Here the landscape rises sharply from the plains, but the mountains in this area are lower than those in the central and western parts of the Himalayas. Due to the heavy annual precipitation of more than 2,000 mm. (80 in.) the mountain slopes are so covered with dense vegetation, jungle, scrub and grass that they are almost impenetrable.

The area is inhabited by various tribes living in a subsistence economy and practising jhum (shifting) cultivation.[1] Except for those on the hill slopes closest to the plains in the Assam Valley there are no automobile roads. The Census authorities have never reached these inaccessible tracts, and, except for a small part of the area closest to the plains, estimates only are available.

N.E.F.A. is administered by the Governor of Assam as the agent of the Government of India. Politically it is regarded as a very important area by the Government of India, due to its location on the Tibetan, Chinese and Burmese borders.

The Naga people have had rather close contact with Christian missionaries and have a high percentage of literacy. However, they are still living in a subsistence economy, practising jhum cultivation. As they did not want to be dominated by the peoples of the Assamese plains, they were continually at war with the Indian authorities from Independence until 1st December 1957, when the conflict was settled by the creation of the Naga Hills — Tuensang Unit, having the same status within the Indian Union as N.E.F.A.

Administratively these two areas do not really belong to Assam. Economically their contact with the peoples of the plains is very limited. Culturally and socially they have their own traditions and characteristics.

(3) *The Hill Districts.* The Hill Districts of Assam; Garo Hills, Khasi and Jaintia Hills, Mikir and North Cachar Hills and Lushai Hills, also differ very much from the plains districts constitutionally and with regard to physical and cultural geography.

While the Lushai Hills are geologically a part of the southern section of the Assam-Burma Ranges, the other three hill districts belong to the Shillong Gneisses. The Shillong Plateau, an extension of the Pre-Cambrian peninsular rocks, forms a barrier south of the Assam Valley. Shillong Peak, the highest point, has an altitude of 1961 meters (6433 feet). On the south slope of this plateau an average

1. See *Tribal Map of India*, Department of Anthropology, Government of India, Calcutta, 1956.

annual precipitation of 10,800 mm. (425.23 in.) has been recorded,[1] but most of the plateau has an annual precipitation of less than 2,500 mm. (100 in.).[2]

Jhum cultivation is also practised by people belonging to the various tribes in the hill districts. As the population increases, there is a tendency towards quicker rotation, and that is the reason why this area is not covered with the heavy jungle vegetation which might have been expected considering the low population density.

The tribes in the hill districts have been in close contact with British rule in India and were strongly influenced by Christian missionaries. Yet they have preserved many of their own cultural traits. They cultivate most of the agricultural products they need, and they are skilled craftsmen. The tribes, however, do not have much contact with each other. To some extent the different groups depend upon trade with the neighbouring plains, and the hill districts cannot be said to form an economic unit by themselves.

Administratively the hill districts, according to the Constitution, are autonomous districts in order to protect the tribes from the influence of the culture of the plains. They are governed by elected district councils and have their own judicial system.

History

Assam, like most other parts of India, has a glorious past. The Brahmaputra Valley has been a meeting place for Indo-Aryan and Indo-Mongoloid peoples. In language, culture, religion and race there is perhaps greater diversity in this north-eastern corner of India than in any other area of the sub-continent. Yet there is no doubt that the people of Tibeto-Burmese origin who have settled on the plains, particularly during the millennium up to 1800, have been absorbed ('Indianized') by the Indo-Aryan Hindu culture.[3]

On the other hand, the numerous tribes inhabiting the hill areas of Assam have lived their own isolated life through the centuries without bothering too much about what was happening on the plains. Most of them are animists, others have been converted to Christianity during the last century.

The last powerful rulers in Assam were the Ahom kings. The Ahoms belonged to the Tai clan of the Shan tribe who had their territories in Upper Burma. They came to Assam in the twelfth century and established a kingdom in Upper Assam. After they had defeated the Koch Dynasty that ruled in Nowgong, Kamrup and west to Cooch Behar, their kingdom covered the whole of the Assam Valley and some of the hill areas.

The Ahom kings defended their area successfully against the Mogul rulers in the west, and the Mohammedans were unable to retain territory in the Assam Valley for any length of time. During the reign of Rudra Singha (1691-1714), Ahom rule was at its peak. Roads, tanks, palaces and temples were built which may still be seen, partly in ruins and partly in good order. The tanks, two of

1. A new rainfall station has been established in Mawsynram, some miles west of Cherrapunji. The Director of Agriculture informed the author that the five year annual average for this station was 12,690 mm. (499.55 in.).
2. See Rainfall Map in *National Atlas of India* (Dehra Dun, 1957).
3. The Assamese language is closely related to Bengali, and about 85 per cent of the people living on the plains have Assamese or Bengali as their mother tongue. In the Assam Valley is found the easternmost branch of Hindu culture. The process of 'Indianization' of the people living there is still going on.

them being about 700 meters square, still lend a particular enchantment to the landscape of Sibsagar District.

As with all past empires on the Indian sub-continent, the Ahom kingdom eventually fell into decline. The Brahmaputra Valley became the battle ground of conflicting religious groups, and rival rulers killing each other. Burmese armies invaded Assam several times in the beginning of the nineteenth century, making the destruction almost complete. The descendants of the Ahoms are today regarded as a backward class.

At the request of one of the Ahom kings the British intervened in the wars of Assam for the first time in 1792. Later, Burmese invaders came into conflict with the British in East Bengal and this led to the gradual British annexation of Assam which was completed in 1838.

There is probably no means of estimating the population of Assam in the days before the civil wars and the Burmese invasions. However, there can be no doubt that the modern districts of Kamrup and Sibsagar, the chief territories of the Koch Dynasty and the Ahom kings respectively, were densely populated. Ruins of palaces, temples, roads and bridges are found in areas which are still covered with jungle or have been cleared in recent times. Descriptions from the days of the old kingdoms also tell of the dense settlements.

When the British defeated the Burmese and made a treaty with them in 1826, the number of people in the Assam Valley was at its lowest. Thousands of Assamese had been carried off as slaves, and thousands of others had been killed with well planned cruelty. Sir Edward Gait mentions especially the district of Nowgong, where, in 1824 some of the helpless Assamese were flayed alive while others were burnt in oil by the Burmese. They so terrorized the people that many fled to the hills and forests of the south, where large numbers died of disease and starvation. The depopulation of the region around Doboka and the Kopile Valley (southern Nowgong) dates from this time. These areas were not resettled until after the First World War. One authority was of the opinion that the Burmese invaders in a period of about twenty-five years destroyed more than half the population of the Assam Valley, which had already been thinned by repeated civil wars and disease.[1]

POPULATION

Growth of Population

Among the densely populated and economically backward countries of Asia, India is in the unique position of having census reports dating back to 1872, with a regular decennial census beginning in 1881. There may be some doubt about the reliability of the figures given in the census reports because of the tremendous difficulties connected with the task of counting such a vast population. However, the reliability is considered to have increased with each new census, so that the 1951 Census is considered to be quite accurate.

The 1951 Census[2] was the main source of information for this section on population, and the figures quoted here are for 1951, unless it is stated otherwise.

The estimated population of the Assam Valley for 1835 was 800,000.[3] The present Lakhimpur District was almost uninhabited, while Sibsagar and Kamrup,

1. Edward Gait, *A History of Assam* (Calcutta, 1926), pp. 283 and 289.
2. *Census of India, 1951*, Vol. 12, Shillong, 1954.
3. Gait, op. cit., p. 299.

the centres of the old Ahom Kingdom and the Koch Dynasty respectively, were densely settled.

The 1901 Census reported a population of 2.6 million in the Assam Valley, indicating a trebling of the population in sixty-six years. Such a rate of growth is reasonable as this was the pioneer period in Assam with almost unlimited areas of land available.

The population of the Assam Valley was almost trebled again during the first half of this century; the number being 6.7 million in 1951. The growth of population in Assam from 1881 to 1931 has been described as extreme because the increase was more than 100 per cent during the fifty year period. A growth at this rate was found only in a few other areas in India during the same period.[1]

Figure 2 shows the growth of population during the present century in the districts of the Assam Valley and in India as a whole. The growth rate of India's population is moderate, about 1.4 per cent per year. All the western countries have had, and many still have, a higher rate of increase of population. Yet the increase of more than five million people every year is a major problem in modern India, because the land is unable to support more people, and there are few jobs for the vast number of unskilled workers entering the labour force.

The extreme increase in the population of the Assam Valley in the twentieth century is due mainly to the new settlement of farmers on the waste lands. The most rapid increase is found in Nowgong (farmer settlements), followed by Lakhimpur where the continuous expansion of the tea industry, the oil industry, veneer mills and other factories is the most important cause of the population growth. Sibsagar District has had the slowest increase in population, but even here the population has increased by more than 100 per cent between 1901 and 1951.

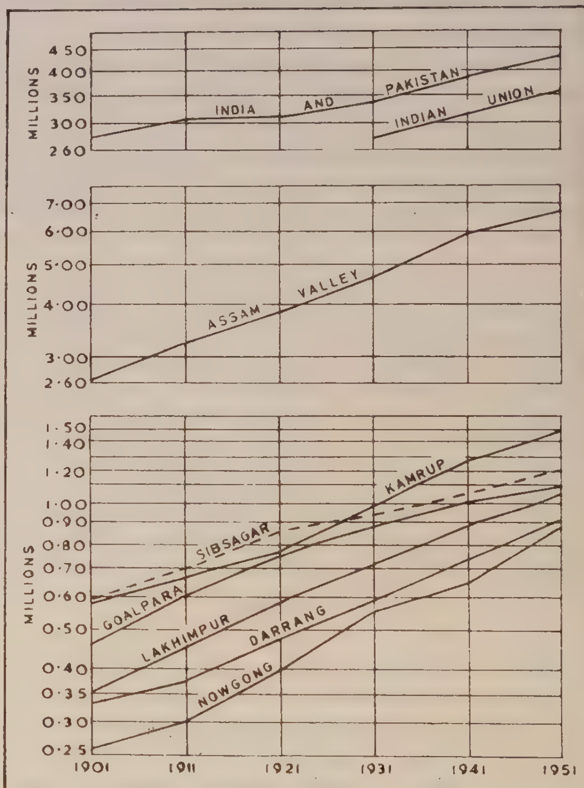

Fig. 2. Semi-logarithmic diagram of the growth of population in the districts of the Assam Valley, 1901 to 1951.

Natural Increase. The rapid growth of population in Assam cannot be due to a higher birth rate than in other parts of India. According to the statistics the birth rate in Assam is much lower than elsewhere in India. The 1951 Census, however, stresses that 'the birth rate figures for Assam are utterly

1. A. Geddes, 'Half a Century of Population Trends in India', *Geographical Journal*, Vol. 98, 1941, pp. 233-5.

inadequate and ridiculously underestimated. They are not only inaccurate and underestimated, but also plainly unbelievable'.[1] Yet one may believe that the natural increase of Assam's population is slower than that of the rest of India, because Assam has suffered severely from epidemics, particularly Kala Azar[2] caused by a parasitic flagellate that infects the spleen, liver and bone marrow. From 65 to 95 per cent of the persons infected by this disease die. It wiped out nearly one fourth of the entire population of Nowgong in the eighteen-nineties.

Migration. Migration plays a major part in explaining the rapid growth of Assam's population. This migration has been of two kinds. In the last half of the nineteenth century British business companies extended their activities into the Assam Valley, bringing in labourers for their estates and industries. In the twentieth century farmers from the adjoining areas have migrated into the Assam Valley and settled on the waste lands.

Conditions for Growth of Population. The British annexation of Assam brought peace to the valley. The opening up of the Assam Valley was dependent upon modern transportation facilities. In 1847 a steamer service was established by the Government, but the boats ran at uncertain intervals and did not proceed beyond Gauhati. The Government's steamer service was later taken over by private companies, and since 1883 there has been a daily steamer service on the Brahmaputra, the route on some days being extended to Sadiya in the far north-eastern part of the valley. During recent years, however, the river has silted up, and today the regular steamer service ends at Tezpur, and Gauhati is the main port in the valley. The railway and the roads now carry most of the traffic in Upper Assam.

The first tea gardens were established about 1840, but the tea industry did not flourish until the eighteen-seventies. In 1872 the area under tea cultivation in the Assam Valley was 110 sq. km. (27,000 acres). In 1901 the production of tea was twenty-two times greater than in 1872.

Small railways and tramways had to be built in several places to bring the manufactured tea down to the Brahmaputra for shipment to Calcutta. A more important event, however, was the construction of the Dibrugarh, Sadiya and Ledo Railway, which was completed in 1885, and brought the tea to the river ports of Dibrugarh and Sadiya. The Assam Railway and Trading Co. Ltd. also started collieries and a brick-kiln in Ledo, which supplied coal and bricks for the tea industry.

The principal railway of pre-independence days was the Assam Bengal State Railway which was opened for traffic in 1905. By means of this line the plains on the southern bank of the Brahmaputra were connected with the port of Chittagong.

Tea Garden Immigration. Much labour was required for this tremendous economic expansion. Labourers were generally not available in Assam and had to be brought from other parts of India, mostly from Bihar. Even today labourers for tea gardens and construction work have to be recruited from other parts of India when needed.

The average Indian regarded Assam almost as a foreign country, and the recruitment of estate labourers for Assam closely resembled the recruitment of Indians for foreign estates. The coolies were hired for a period of five years and were kept almost as prisoners in concentration camps for the duration of their contracts. Not until 1921 was there any legislation to protect the tea garden

1. *Census of India, 1951,* Vol. 12, Part I-A, p. 85.
2. Sometimes called Black Fever.

coolies. Today the labourers in the tea gardens have a more dependable income, better medical care and better social security than most of their countrymen.

Many hundreds of thousands of tea garden coolies have moved into Assam. The chief recruitment of labour seems to have occurred between 1911 and 1921, when, according to Immigrant Labour Reports, 769,000 new coolies entered Assam. The number of the coolies who have returned to their homes is uncertain, but the proportion is believed to be high.[1] On the other hand the extreme growth of Assam's population proves that many must have taken up land and stayed on as farmers.

There is now a downward trend in the recruitment of tea garden labour from places outside Assam. As health conditions improve, the natural increase of the estate population makes it possible to secure local labour.

Governmental Views on Immigration about 1900. As the tea gardens expanded in the nineteenth century, it became impossible to get sufficient rice supplies from the Assamese farmers, and rice had to be imported from Bengal. Attempts were made, by the interested companies, to persuade farmers to cultivate land in order to provide cheap rice in Assam. However, a resolution by the Government of India dated 19th October, 1888, stated that 'the obstacles of climate and language and the risks to the health of the people coupled with the initial mortality to be expected, had led to the conclusion that it would be unwise to hasten the development of the Assam waste lands'.[2]

In 1899 the Chief Commissioner of Assam was of the opinion that 'The high mortality of Assam is not necessarily of long duration. As soon as the tree growth has been cleared and the land exposed to the action of the sun and air the unhealthy influences soon pass away and many of the healthiest tea gardens in the province are those which only a few years ago had very heavy death rates'.[3] He suggested that the Government of India should authorize a colonization scheme under zamindars. The same source states that in 1875 the import of rice to Assam was 15,000 tons, and by 1896 the rice imports had almost doubled.

The Government of India, however, was of the opinion that the land should be opened up by the tea industry, and nothing was done to encourage farmers to settle in the Assam Valley. Not until the present century did farmers begin moving into Assam from adjoining countries.

Farmer Immigration. The 1891 Census Report stated that 'It might have been thought that the amount of cultivable land available, the fertility of the soil and the low rents prevailing would have induced some portion at least of the overcrowded cultivators of Bengal to find their way to Assam and take up land there. But this does not appear to be the case. The coolies for the tea gardens come to Assam because they are more than usually indigent and are specially recruited and brought to the province at the expense of the persons for whom they are to labour. No such inducements exist to bring farmers to Assam to take up land for cultivation and they therefore do not come'.[4]

In 1901 the immigration of farmers had still not started, but in 1911 the census authorities reported that the first wave of settlers had reached Goalpara. The number of persons living in Goalpara in 1911 who were born outside Assam was 118,000, of which 77,000 came from districts in Bengal, mostly Mymensingh,

1. Kingsley Davis, *The Population of India and Pakistan* (Princeton, 1951), p. 116.
2. *The Story of the Assam Railways and Trading Company Limited, 1881-1951* (London, 1951), p. 58.
3. *The Colonization of Waste Lands in Assam* (Calcutta, 1899).
4. *Census of India, 1891,* Volume on Assam.

Pabna, Bogra and Rangpur (see Table 2). These East-Bengalis were the advance guard of an army of about one million farmers who have settled on the waste land in the Assam Valley.

As shown in Table 2, the wave of immigrant Bengali farmers had not reached the districts east of Goalpara in 1911. The 28,000 Bengalis enumerated in the districts of Sibsagar and Lakhimpur in 1911 (there were no Mymensinghias) were probably working in the tea gardens and in industry.

In 1921 the settlers had reached Kamrup, Nowgong and Darrang. Since then the number of immigrants has increased in each new census. The sex and age figures given in the 1921 Provincial Table IV[1] show that the colonists were settling in family groups. The men generally came first in order to secure land and build houses, their families following later. About 85 per cent of the settlers were Muslims and 15 per cent Hindus.[2]

TABLE 2: IMMIGRANTS INTO THE ASSAM VALLEY FROM BENGAL AND PAKISTAN (in thousands)

District	Immigrants from Bengal			Immigrants from Pakistan 1951*
	1911	1921	1931	
Goalpara	77 (34)	151 (78)	170 (80)	136
Kamrup	4 (1)	44 (30)	134 (91)	186
Darrang	7 (1)	20 (12)	41 (30)	84
Nowgong	4 (1)	58 (52)	120 (108)	173
Sibsagar	14 (Nil)	14 (Nil)	12 (Nil)	26
Lakhimpur	14 (Nil)	14 (Nil)	19 (2)	61
Total, Assam Valley	120 (37)	301 (172)	496 (221)	666

Numbers in brackets show immigrants from Mymensingh, the home of most of the settlers. The majority of the Bengali immigrants were born in East Bengal.
*Only about 20,000 people living in the Assam Valley in 1951 were born in West Bengal.
Source: *Census of India, 1951,* Vol. 12, Part I-A, pp. 73 and 74.

Of the 666,000 persons living in the Assam Valley in 1951 and born in Pakistan, 167,000 were classified as refugees. There was only a slight preponderance of men over women, which is a clear indication of the permanent nature of this immigration. The Annual Land Revenue Administration Reports state that most of these immigrants have taken up land and settled as farmers. Between 1931 and 1951 waves of immigrants reached Lakhimpur District, settling mostly in the North Lakhimpur sub-division.

The Superintendent of Census Operations in Assam in 1931 characterizes the mass immigration into the Assam Valley in these words:— 'Where there is waste land thither flock the Mymensinghias. In fact the way in which they have seized upon the vacant areas in the Assam Valley seems almost uncanny. Without fuss, without tumult, without undue trouble to the district revenue staffs, a population which must amount to over half a million has transplanted itself from Bengal to the Assam Valley during the last twenty years. It looks like a marvel of administrative organization on the part of the Government, but it is nothing of the sort: the only thing I can compare it to is the mass movement of a large body of ants'.[3] They opened up vast tracts of dense jungle along the south bank

1. Cited in *Census of India, 1951.*
2. The 1921 Census reported 69 per cent of the total population in the Assam Valley as Hindu, and 15 per cent as Muslim. It was, however, remarked that the percentage of Hindus might be too high because the borderline between Hinduism and Animism was very vague in Assam. See *Census of India, 1921,* Vol. 3, Assam.
3. *Census of India, 1931,* Vol. 3, Shillong, 1932, Part 1, p. 51.

of the Brahmaputra and occupied nearly all the lands which were open for settlement in this tract. They brought wealth, industry and general prosperity to the whole district.

Non Farmer Immigration. The total number of persons born outside Assam and enumerated in the Assam Valley by the 1951 Census amounted to 1,106,000. In addition to the 666,000 Pakistani immigrants, 396,000 persons were born in India in places other than Assam, and 44,000 persons were born in foreign countries excluding Pakistan.

Most of the 396,000 non-Assamese Indians probably did not come to the Assam Valley permanently. They were mostly labourers for the tea gardens and wage earners in industries and in construction work. About half (195,000) were born in Bihar and 82,000 in Orissa, while 25,000 and 22,000 were born in Uttar Pradesh and Madhya Bharat respectively. The sex ratio of these population groups indicates the semi-permanent nature of their immigration. Among the Biharis there were 575 women per 1,000 men, and among the Oriyas there were 775 women per 1,000 men. The sex ratio for the immigrants born in Uttar Pradesh and Madhya Bharat was 475 and 720 respectively.

Immigrants from other places in India are not numerous. About 20,000 have come from the neighbouring State of West Bengal — men and women in an equal proportion. This is probably a permanent settlement both of farmers and of educated middle class people.

Even if they are few in number, attention must be given to the people from Rajasthan and Punjab. The 15,000 Marwaris from Rajasthan handle most of the wholesale and retail trade in the Assam Valley. The sex ratio among the Rajasthanis is 500 women per 1000 men. The Punjabis, mostly Sikhs, numbered 3,800 with a sex ratio of about 500 women per 1000 men. They are mainly occupied as contractors, skilled mechanics, drivers, carpenters and enlisted men and officers.

Of the people born in foreign countries, excluding Pakistan, most have come from Nepal. A number of retired soldiers from Ghurkha regiments have taken up land and become farmers. Many of them are using their land for grazing buffaloes and selling milk and ghee.[1] Nepalis are also found as peons[2] in offices, drivers, mechanics and carpenters. Of the 1,200 born in European countries, 813 were men who for the most part became the managers of the tea industry. The number of Europeans is declining even though the tea estates are still mostly owned by British companies.

The Significance of the Immigration. There can be no doubt that the 1.1 million people (17 per cent of the total population), who, according to the 1951 Census, were born outside Assam, are immigrants. But how many are descendants of immigrants who moved to Assam during the last century? This question is difficult to answer, because the Census did not enumerate these people. However, the language situation may give some indication as to the proportion of immigrants in the population of Assam.

According to the 1951 Census, 74 per cent of the people in the Assam Valley had Assamese as their mother tongue, while not more than 815,000 (12 per cent) had Bengali as their mother tongue. This is only a little more than the number of people born in Bengal, but the Superintendent of Census Operations points out that the figures 'reflect the aggressive linguistic nationalism now prevailing in Assam . . . It is not unlikely that some amongst the persons who have returned

1. Clarified butter.
2. Orderlies.

their mother tongue as Assamese have done so from devious motives, even though their knowledge of Assamese does not amount to much.'[1]

The language situation in 1931, however, gives a better indication of the immigration pattern, as in that census much emphasis was placed on obtaining correct reports on languages spoken by the people. Not more than 42 per cent of the population then was reported as having Assamese as its mother tongue. Bengali was spoken by 25 per cent, and 8 per cent had Hindi as their mother tongue.

Of the remaining 25 per cent about one half (526,000) spoke a vernacular language mainly of Austric or Tibeto-Chinese origin. The most important of these spoke Boro (called Bodo or Plains Kachari), Mikir and Miri. The other half spoke different Indian and foreign languages, of these Oriya (162,000), Mundari (148,000), Santali (92,000) and Nepali (101,000) were the most important.

Through the centuries Assam has been a meeting place for various Indo-European and Asiatic peoples whose cultures have influenced each other and sometimes existed side by side in the Brahmaputra Valley. The recent invasion of Assam is of a different character, as people now immigrate mainly as single persons, families or small groups. The available information about the language situation in 1931 and immigration indicates that a little less than one half of the population of the Assam Valley today are immigrants or descendants of immigrants.[2]

The technical culture of our time would, of course, have conquered Assam sooner or later. The large scale immigration of the last century, however, accelerated the modern development, because so many newcomers brought with them new ideas, other traditions and different ways of life, influencing the social and economic life of their new environments.

Spate states that 'the Assamese themselves appear to have their share of Indo-Chinese insouciance, pleasant indeed, but unpractical'.[3] This is in line with the author's impressions and, if correct, these characteristics may explain why the immigrants play such an important part in the economic life of Assam. They work at trades which the Assamese themselves have taken up only to a small extent. The tea, oil and coal industries have been established and managed by foreigners or Indians alien to Assam. Marwaris of Rajputana do the trading, the Sikhs and Nepalese are the mechanics, carpenters and skilled workers. The Assamese have to compete with well educated and qualified Bengalis and South Indians for the professional positions they desire so much.

The coolies working on the tea estates, in industry and the construction of buildings, roads and the huge revetments on the banks of the Brahmaputra, are mostly from Bihar and Orissa. The greatest number of illiterates is found among these coolies and the farmer immigrants, particularly the Muslims from East Bengal. Yet these people represent a valuable element in the population of Assam. Both the Census Reports and the Land Revenue Administration Reports

1. *Census of India, 1951,* Vol. 12, Part I-A, p. 414.
2. The equation below is in line with this statement:—

$$\text{Population in 1835 X } \left(1 + \frac{x}{100}\right)^{n} = \text{Population in 1951} \div 2$$

$$\text{Thus} \quad 800{,}000 \left(1 + \frac{x}{100}\right)^{115} = \frac{6{,}690{,}000}{2}$$

$$\text{Therefore} \quad x = 1.3$$

(x = annual percentage increase. n = number of years)

An annual increase of 1.3 per cent in the population since 1835 would have resulted in a population of 3,345,000 in 1951, if immigration had not taken place. 1.3 per cent is about the same as the natural rate of growth of the Indian population today.

3. O.H.K. Spate, *India and Pakistan* (London, 1957), p. 563.

point out that their methods of farming are much better than those of the indigenous farmers. Their skill has been an inducement to improved farming among the indigenous farmers.

It is interesting to observe the strict segregation of the different Indian communities in Assam. It looks as if the language is the tie which keeps the groups together. Families that may have lived for generations in Assam, still retain their Bengali language and their tradition.

During the last century a large number of different population groups came to Assam where they have had to live together and to contribute to the welfare of the State. This immigration has sometimes led to open conflicts, particularly during the last decade in the Goalpara District, where so many Bengalis moved in that they almost conquered the district culturally. The Bengali and Assamese languages are very closely related and the language spoken in Goalpara today, a mixture of Assamese and Bengali, is often called Goalpari. The caste system has never been as rigid in Assam as in other parts of India. Yet it is obvious that it is not easy to mix the different groups and make them work together as they should in a modern state. Independence has also given rise to an Assamese nationalistic movement, putting the Assamese traditions in the foreground and imposing the Assamese language and culture on the immigrants. Assam is struggling with the problems of adapting the state to a larger population with new economic activities, and of absorbing the newcomers socially in order that the Assamese language and culture may be preserved and developed further.

Livelihood

In the Assam Valley 73 per cent of the people belonged to the agricultural classes (owners, cultivators or labourers) as compared with 70 per cent for all India in 1951. Even in the towns it was found that 7 per cent of the people belonged to the agricultural classes. A visitor to an Assamese town gets the impression that many families keep cows, goats or chicken, and that agriculture is an additional livelihood for many of the town dwellers.

However, nearly 12 per cent of Assam's population are dependant upon the tea industry which is classified in the census as a non-agricultural livelihood. If the labourers on the tea estates are added to the total for agriculture, it appears that 85 per cent of the people in the Assam Valley derive their income directly from agriculture. Assam ranks second among the states of India in the percentage of its people dependant upon agriculture. In 1951 Bihar was first, with 86 per cent of its population belonging to the agricultural classes.

Except for the match factory in Dhubri and the Assam Oil Company in Digboi, with 1,200 and 3,000 labourers respectively in 1956, no large scale industry is found. Some coal mining is carried out in the Ledo area. Of the remaining 15 per cent of the population, 5 per cent are engaged in commerce and transport while the rest are mainly occupied in small scale industries, handicraft and miscellaneous jobs and services, mostly in the villages.

Urbanization

The extremely high percentage of people deriving their means of living from agriculture results in a low degree of urbanization. Assam is the least industrialized and urbanized state in India. Only 4 per cent of the population live in the nineteen so-called towns of the Assam Valley, Gauhati being the largest with 44,000 inhabitants and North Lakhimpur the smallest with 3,100, according to the 1951 Census. The location of the more important towns may be seen in Fig. 1.

Shillong, the State Capital, was one of the popular hill stations of British India, its surroundings were called the 'Scotland of the East'. Its position as

a tourist centre, however, was greatly reduced after the Partition. In 1951 Shillong with its cantonment had a population of about 54,000. Since Independence the number of inhabitants has increased as Government activities expanded.

The capital is situated in the Khasi and Jaintia Hills at an altitude of 1,750 meters (5,300 feet). Because of the hilly landscape it has been too costly to construct an airfield. Only one road, 100 kilometers (65 miles) long, and so narrow and winding that only one-way traffic is allowed, connects Shillong with the plains. The pleasant climate of the hills is the main advantage which Shillong offers as a capital. The people of the plains feel that the capital should be moved to one of the towns in the Assam Valley where the majority of the people could be better served, and where the authorities of the State could keep contact with the people whom they govern.

Gauhati, the District Headquarters of Kamrup, with its 44,000 inhabitants, is situated almost in the middle of the valley on the south bank of the Brahmaputra. Its site is protected by low hills, outliers of Shillong Gneiss, which have made Gauhati safe from floods and erosion. Gauhati is in many ways the leading town of the Assam Valley. The railway from West Bengal crosses the Brahmaputra at Pandu — six miles downstream from Gauhati. Gauhati has a good steamer ghat, and the importance of the town has increased considerably in recent years since the silting up of the river has prevented steamers from proceeding beyond Tezpur. This has meant the reloading, in Gauhati, of goods to and from Upper Assam's south bank. The significance of Gauhati as an administrative centre is also increasing, not only because of its position as the headquarters of Kamrup District, but because some governmental institutions, such as the High Court and the University, have transferred to, or were established in the town.

Various reasons can be given for the establishment of towns in the Assam Valley. The headquarters of the districts were selected during the British period, but towns were found on these sites in former times as well. Their significance has changed through the centuries. Dhubri and Tezpur, particularly, have excellent sites as they, like Gauhati, are protected by solid rocks — fragments of Shillong Gneiss. Both have important steamer ghats. Dhubri (23,000 inhabitants) has a large match factory, while Tezpur (19,000) is the centre for the tea estates of Darrang. Nowgong and Jorhat, situated some distance from the Brahmaputra, are also very old towns. Nowgong, with a population of 28,000, is the headquarters of Nowgong District, Jorhat (16,000) is the centre for the tea estates in Sibsagar District. Dibrugarh (38,000) is the leading town and commercial centre of Upper Assam, but it is liable to severe flooding. After a big earthquake in 1950 a large part of the town was carried away by the river. River steamers do not now go as far upstream as Dibrugarh, and this may reduce its importance as the commercial centre of Upper Assam.

There are a few other towns in addition to these six district headquarters. Barbeta in Kamrup, north of the Brahmaputra, is the largest, with 21,000 inhabitants. Most of these towns, like Lumding (15,000) and Tinsukia (12,000), have railway stations which have made them local centres or junctions with workshops. Digboi and Margherita are the only places based on industrial activities.

Trade among the different towns and districts is small in volume and of limited importance, because manufactured goods are only produced to a small extent in Assam, and because agriculture is mainly at the level of subsistence production.

The small size of Assamese towns explains the lack of internal differentiation. Their main characteristics are the bazaars with the shopkeepers and their families living in the same building as the shop. There is at least one market place for the

sale of products sent by the farmers of the vicinity. The houses are mostly small huts with a semi-permanent look, and one is tempted to think that no one is responsible for keeping the roads and the sewage system in order.

The only towns which look as if they have been planned are Digboi and Dibrugarh. The Assam Oil Company is responsible for the town of Digboi. In Dibrugarh the Municipality Board has had to invest large sums of money in roads and the sewage system due to the floods. As in Digboi, the population of Dibrugarh consists mainly of people from places outside Assam, and who enjoy a better income and are used to a higher standard of living.

The ratio of females to males in the population of the Assam Valley in 1951 was 0.862 to 1. West Bengal, with 0.859 to 1, was the only Indian state with a lower sex ratio. The sex ratio for all India was 0.947 to 1. The preponderance of men in West Bengal is due to the extraordinary low ratio of 570 females per 1,000 males in Calcutta which has absorbed so many men from the countryside and the neighbouring states of Orissa and Bihar. The distribution of the population by sex in the Assam Valley must be explained by the semi-permanent immigration of men into the Valley.

Urban life generally has not attracted Indians. Many of the town dwellers regard their stay in town as temporary. The men leave their families in the villages when they go to town to find a job. This fact is reflected in the sex ratio of the Assam Valley urban population which in 1951 was 0.650 to 1. In 1921 the sex ratio was not more than 0.600 to 1. The increase in female ratio during the thirty years prior to 1951 must be regarded as an indication that Indians are gradually becoming aware of the value of towns, and their discovery that family life can be rich here too. This new attitude to town life will in turn gradually change the structure of the towns.

With the expanding economy of modern India the occupational pattern is changing. The importance of the town is growing and the number of town dwellers is increasing. This process is only in its very beginning in Assam. As the economic structure of Assam changes, one would expect that the increase in urban population will first take place in the existing townships. With further expansion, however, new townships will probably grow up.

Density of Population

In spite of the immigration, the plains along the Brahmaputra are still sparsely populated compared with the other river plains of India and South-east Asia. The average population density in 1951 was not more than 127 per sq. kilometer (329 per sq. mile) in the Assam Valley compared with 310 per sq. kilometer (803 per sq. mile) in the State of West Bengal. However, West Bengal is strongly urbanized. If the rural population of the Assam Valley is compared with the rural population of West Bengal, the population density in the latter area is still almost double that of the Assam Valley (234 per sq. kilometer in West Bengal and 122 per sq. kilometer in the Assam Valley, or 606 and 307 per sq. mile respectively).

East Bengal (Pakistan), a predominantly rural area very close to the Assam Valley, had a population density in 1951 of almost 300 per sq. kilometer (770 per sq. mile). In the Tonking delta, the area with the densest rural population in tropical and humid Asia, the population density is 450 people per sq. kilometer (1,166 per sq. mile), almost four times as great as in Assam.[1]

Studying the map of the population density in the different districts and subdivisions of Assam (Fig. 3), it is evident that the population is unevenly dis-

1. Pierre Gourou, *Tropical World* (London, 1953), p. 99.

tributed on the plains. The highest population density of Assam State is found in Cachar, particularly in the subdivision of Karimganj.[1] It is an indication of the relationship of this area to Bengal. The subdivisions of Sibsagar and Kamrup (north of the Brahmaputra) are the most densely settled areas in the Assam Valley, with a density of about 167 per sq. kilometer (430 per sq. mile). This is much less than the average population density of the adjacent plains of the Ganges-Padma. North Lakhimpur (71 per sq. kilometer, 184 per sq. mile) and Golaghat (95 per sq. kilometer, 246 per sq. mile) are the most sparsely populated areas.

The District of Goalpara on the Bengal border has a density less than the average population density in the Assam Valley. This remarkable fact may be explained in part by the soil conditions in the Eastern Duars, but the main reason is probably that the British from their first days in Assam introduced the Bengali zamindari system of land tenure in Goalpara. The first settlers in the valley stopped in Goalpara, but, as the land situation further east became better known, the immigrants preferred to take up land under the ryotwari system prevailing in the other districts. Communal disturbances in 1950-51 may also have contributed to the low population density, because some Muslims temporarily left their homes in Goalpara during the disturbances. Their number, however, is not known.

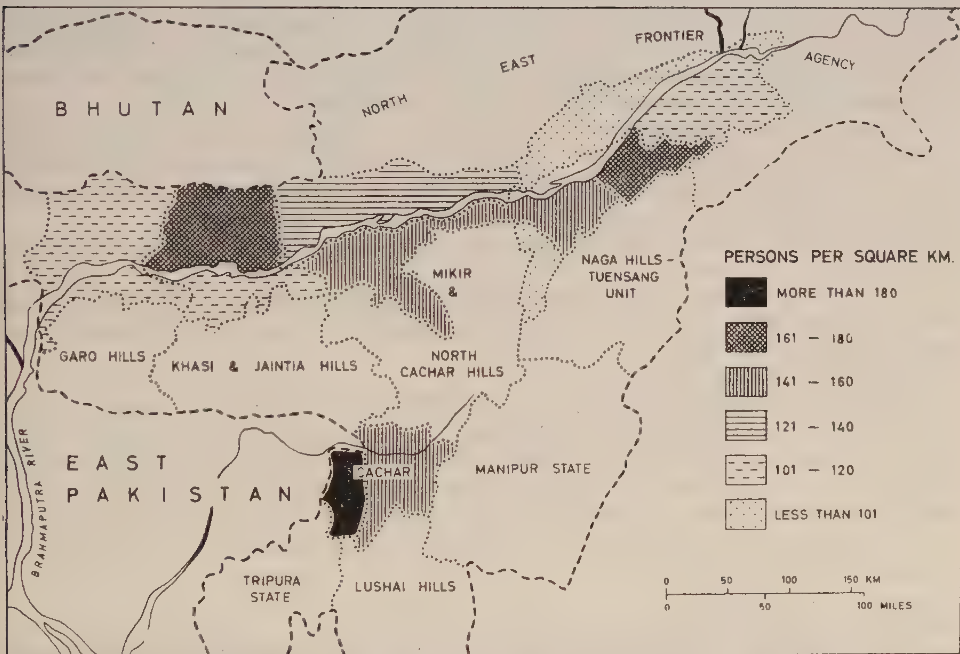

Fig. 3. Population density in the Assam Valley and Cachar, 1951. (Equivalent densities in persons per square mile are; less than 260, 260-311, 312-363, 364-414, 415-466, more than 466).

The relatively low population density in the Assam Valley today is surprising. Students of Indian agriculture, and of the economy generally, characterize the countryside of the sub-continent as 'over-populated'. However, the population situation described above, and the immigration which is still taking place, indicate that the Assam Valley must be regarded as 'under-populated' according to general

1. The calculated figure for the population density in Karimganj subdivision is 206 persons per sq. kilometer, or 534 per sq. mile.

Indian standards. If this is correct, the Assamese farmers are in the favourable position of not having experienced the pressure on the land which is so serious in other parts of India.

Even a casual visitor looking at the landscape will notice the large areas of uncultivated land in the Assam Valley. The question arises as to whether the land suitable for agriculture is fully occupied so that the optimal population density based on the general cultivation and methods of Indian farming is already reached. There are reasons for thinking that there is still room for a further expansion of the farmland and for a higher density of rural population in the Assam Valley. This supposition, however, cannot be proved until the existing land utilization has been more closely examined.

LAND UTILIZATION

The statistics published by the Ministry of Agriculture in Assam regarding land use in the plains divisions are estimates — if not guesses — made by the Deputy Commissioners of the districts. The so-called 'village papers' which are available in some of the other Indian states, are not found in Assam. The tables showing the production of the different crops are also based on estimates or informed guesses. For the 'reserved forests' the area has been measured by the Conservator of Forests, and the figures given may be accepted. Also, for the tea gardens reliable statistical information is available as the tea garden companies are obliged to make accurate reports to the Government.

Until careful and detailed field mapping of the present land use has been carried out, research work must be based on the statistical information published by the Director of Agriculture. Even if this information is in rather rough form, the figures give a general picture of agriculture and land use.

The following terms may be used for the classification of land in the Assam Valley.[1]

(1) *Forests.* Forest areas reserved by the Government under the Assam Forest Act and administered by the Forest Department. These forests are not open for settlement, and cutting is controlled.

(2) *Tea Garden Land.*

(3) *Net Area Sown and Fallow Land,* also called Cultivated Land.

(4) *Uncultivated Land or Waste Land.* The main part of this land is described as 'unclassed State Forests' and nominally it is administered by the Forest Department. Smaller areas of waste land are at the disposal of village panchayats. This is the type of land on which the immigrants have settled.

(5) *Uncultivable Land,* areas occupied by rivers, ponds, hills, roads, towns, villages and so forth.

Forests

Approximately 16,100 sq. kilometers (about 6,200 sq. miles), or 12 per cent of the total area of Assam (excluding N.E.F.A.), is covered with forests which are under the control of the Forest Department.

Immigration into the Assam Valley has caused serious difficulties for the forest authorities. One major problem has been to prevent squatters from occupying forest areas. The foresters of Assam are fully aware of the need for forest products in the economic life of the country, and the necessity for preserving the forest vegetation in order to control soil erosion. The Senior Conservator

1. Land in the Assam Valley must be regarded as owned by the Government. In Goalpara the zamindari system of land tenure is dominant. In the other districts the ryotwari system of land tenure is practised. Except for the zamindari owned estates of Goalpara the settlement of farmers is regulated by the Government.

of Forests has stated that '... in the race for land which is on, the forester is being left behind.... The actual percentage of reserved forests to the total area of Assam is about 12 per cent, whereas according to accepted international scientific standards it should be about 25 per cent.'[1]

The author is of the opinion that the worried forest authorities do not distinguish carefully enough between forest areas in the plains districts and those in the hills. On the plains one may allow much less than 25 per cent of the land to be covered with forests, while in the hills it might be preferable if more than 50 per cent of the area could be forest land. In the hills, however, the Government cannot reserve forests by legislation only, because of the autonomy granted to the hill-peoples and because of the practise of jhum cultivation. The serious problem of deforestation on the hill slopes surrounding the Assam Valley can only be solved by teaching the hill-peoples improved methods of farming, and by supplying them with better farm implements.

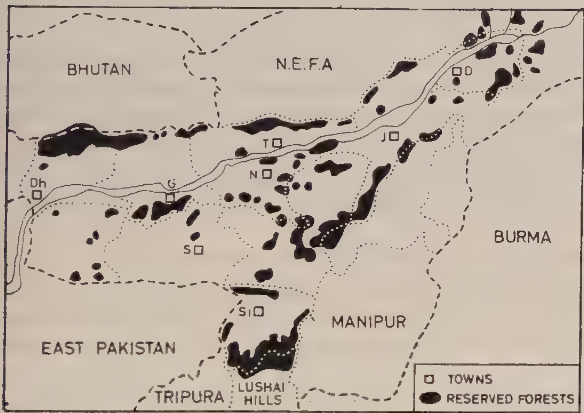

Fig. 4. Forest areas in Assam, reserved and controlled by the Government.

The location of forest reserves in Assam is shown on Fig. 4. The main portion of the reserves is found within the plains districts. Only 3000 to 4000 sq. kilometers (1,100 to 1,500 sq. miles) of the forest reserves are located within the hill districts. The forest reserves within the plains districts are estimated to cover an area of 12,000 to 13,000 sq. kilometers (4,700 to 5,100 sq. miles), or about 20 per cent of the land.

The areas of the forest reserves are not reported separately for each of the districts because some of the reserves are located within two or three districts. For the districts of Goalpara, Kamrup, Darrang and Lakhimpur the area under forest is 22, 11, 30 and 10 per cent respectively.

The Assam Valley is probably the only fertile river plain in the densely populated parts of tropical Asia which has conserved such a large proportion of land under forests.

Most of the forests are located at the outer edges of the plains. The Sal (*Shorea robusta*) forests in Goalpara are of the greatest significance, as this type of wood is valuable for railway sleepers and construction material. In Upper Assam the evergreen forests consist to a large extent of hardwood trees. Hollock (*Terminalia myriorcarpa*) and Hollong (*Dipterocarpus macrocarpus*) are used in veneer mills and for making tea-chests. Simul trees (*Bombax malabaricum*) are used by the match factory in Dhubri. For domestic use bamboo is indispensable, and some of the bamboo species may be of even greater value in the future if paper mills are established.

A maximum yield is generally not taken from the forests of Assam, mainly because the demand for timber in Assam is limited. The Chief Conservator of

1. P.D. Stracey, *Assam's Economy and Forests* (Shillong, 1949), p. 1. The same conclusion is reached by H.P. Das in an unpublished Ph.D. thesis, '*The Forests of Assam: A Study in Economic Geography*' (London School of Economics and Political Science, 1954).

Forests has stated that the forest production can be considerably increased if capital investments are placed at his disposal, and if he is provided with a larger staff of qualified foresters. The revenue from the forests amounted to 6,723,000 Rupees (£500,000) in 1954-55, of which only a small sum was used for administration and investments.

Within the forest reserves, but not included in the figures already quoted, there is an additional 650 sq. kilometers (250 sq. miles) devoted to cultivation, mostly of a permanent nature. These forest village communities supply the forest authorities with labourers. The Forest Department is willing to provide land for more forest villages in areas suitable for paddy, so as to increase the Department's labour force. However, the Bengali immigrants are not inclined to settle on patches cleared in the jungle, and some of the tribes, who are interested in life in the jungles, do not wish to be employed in forest operations, and their methods of farming are generally poor.

Tea Garden Land

Of the total area under tea in India in 1951 (3,150 sq. kilometers, 779,000 acres) about 50 per cent was in Assam (1,560 sq. kilometers, 386,000 acres) on about 1,000 estates. However, tea gardens in Assam occupy much more land than is actually used for tea bushes, that is, 5,950 sq. kilometers (2,300 sq. miles),[1] or 10 per cent of the area of the plains districts. Ninety-two per cent of the tea garden land is located in the three districts of Upper Assam; Lakhimpur, Sibsagar and Darrang.

Part of the land not under tea cultivation consists of forests of mixed quality. The tea gardens have to produce their own power, and many of them use wood as fuel for steam power because it can be cut in their own forests. The low lying land within the tea gardens is sometimes used by the labourers for the cultivation of rice.

Although new land has not been brought under tea cultivation since the Second World War, that the production of tea has increased considerably is due to capital investments and better methods of cultivation. About 500,000 labourers in Assam were permanently employed on 1,560,000 decares (386,000 acres) of land in 1951. It is remarkable that 3 decares (0.75 acre) of tea garden land will support one labourer, indicating that tea cultivation may result in a higher population density than paddy cultivation. These calculations are confirmed by Ghose who states that the average employment in Dooars, West Bengal, is about one worker per acre.[2] He adds that although the yield per acre has been increasing every year since the war, the output per worker is decreasing, and the wages are rising.

Cultivated Land

The dominating features of the countryside in the Assam Valley are the paddy fields and the villages. The houses are located within a dense vegetation of bamboos, bananas, plantains and palms.

According to the agricultural statistics, 38 per cent of the area of the Assam Valley (not including land under tea bushes) is cultivated. The percentage of cultivated land to the total area in the various districts is: Goalpara 30, Kamrup 43, Nowgong 44, Darrang 48, Sibsagar 40, and Lakhimpur 27. Except for Darrang these figures correspond roughly with the figures for the population densities, that

1. *Tea in India, 1951*, Ministry of Food and Agriculture, Government of India, New Delhi, 1954.
2. *Assam Review and Tea News*, Calcutta, February, 1957.

is, Goalpara 107 persons per sq. kilometer, Kamrup 150, Nowgong 158, Darrang 125, Sibsagar 135 and Lakhimpur 102.

A rough comparison may be made between the plains of West Bengal, where 70 to 80 per cent of the area is cultivated and the density of rural population is about 250 per sq. kilometer, and those of the Assam Valley where the population density is 122 and about 38 per cent of the land is cultivated.

The Main Corps. The farmers of Assam are dependant upon the cultivation of wet paddy to a larger extent than in other parts of India. Winter rice (*Sali* in the Assam Valley, *Aman* in Bengal), sown during the monsoon, occupies more than three quarters of the area under paddy, while the remaining paddy land is sown mainly with autumn rice (*Ahu* in the Assam Valley, *Aus* in Bengal) during the early rains in March-April.

About 75 per cent of the cultivated area in the Assam Valley is paddy land. Plantings of other cereals are insignificant. Twelve per cent of the cultivated area is used for the production of different food crops — pulses, potatoes and oilseed plants such as rape and mustard. Chilly, pepper and other spices are grown, but such plants cover an insignificant part of the agricultural land.

Jute is the only cash crop of the Assam Valley. The production of jute increased after the Partition, when the jute mills in Calcutta were cut off from the jute cultivators of East Bengal. Transport costs to Calcutta, however, are high and it is mainly the Bengali farmers in Lower Assam, Goalpara, Kamrup and Nowgong, who have taken up jute cultivation. The area under jute covers about 10 per cent of the cultivated land.

The Quality of Farming. The list of defects and deficiencies in the methods of Indian land utilization is almost infinite. The productivity of the land is extremely low, the methods of cultivation are old fashioned and the small size of the holdings and fragmentation of the fields prohibit efficient production. The social system does not encourage initiative.[1] Capital for investment in improved agricultural practice is not available.

A short walk through a village is sufficient to see that Assam is no exception to the general rule. The small garden plots around the farmers' houses are badly cared for. The banana trees yield a small and low quality fruit. Filth and weeds are in abundance.

The farmers of Assam harvest their fields only once a year. Yet they are better off than farmers elsewhere in India, because the rains never fail and Assam has consequently never suffered from famine. In the nineteen-twenties and -thirties Assam produced sufficient rice for its own consumption, but since the Second World War rice and food grains have been imported. Improvements in agriculture could be made so that Assam would again become self supporting in rice and cereals.

The Land Holdings. During the years 1948 to 1951 a sample survey was conducted by the Director of Statistics which revealed that the average size of 20,952 ownership holdings was 14 bighas or about 20 decares (5 acres).

However, not all the owners use the land which they possess. The average size of the holdings operated was found to be 16 bighas or about 22 decares (5.5 acres). In Assam the farms are worked by family units. One family of five to six persons (the average size of families in the Assam Valley) with two bullocks, are able to farm up to three or four acres. Farmers having 16 to 20 decares of

1. Joint families, caste and religious traditions are the main causes for the general absence of incentive. Kingsley Davis, *The Population of India and Pakistan* (Princeton, 1951).

land (4 to 5 acres) should thus be well off by Indian standards, as on that area they should be able to produce much more rice than they consume, and still have fallow land for grazing cattle.

Many farmers, however, have holdings smaller in area than the average size in the sample. Thirty-five per cent of the families operate farms with areas less than 13 decares (3 acres). Fifty-six per cent of the farms are of medium size ranging from 13 to 45 decares (3 to 11 acres), and 9 per cent of the families have more than 45 decares (11 acres) of land.

Fragmentation of the farms is often considered to be an indication of low quality farming. One must, however, admit that if the plots are not situated too far from each other a smaller degree of fragmentation (two to four different plots, depending on the size of the farm) may offer certain advantages, because fragmentation allows the farmers to have plots of land on both light and heavy soil and at different elevations.

A detailed sample survey of the land holdings in Darrang and Sibsagar Districts was reported in the 1951 Census. It was found that, on an average, a farm consisted of 4 to 5 separate plots. In several instances, however, farms of 8 to 13 decares (2 to 3 acres) were divided into 20 or more separate plots. The small farms are relatively more fragmented than the medium and large ones, with the result that the plots on the small farms are particularly minute.

The sample survey also disclosed the fact that the villages of the indigenous Assamese had the highest percentage (49 per cent) of land holders with small farms. These farms were also badly fragmented.

The Waste Land

The utilization of 68 per cent of the land in the Assam Valley has been discussed in the previous paragraphs. The question remains as to how much of the remaining one third of the land can be used for agriculture. The agricultural statistics provide no answer to this, as the remaining land is described as 'Unclassed State Forests'. The question can therefore be discussed only in terms of physiographic factors and how they limit the possibilities for cultivation on the plains.

Precipitation. None of the rainfall stations on the plains has an annual average precipitation of less than 1,220 mm. (48.10 in.). Most of the recording stations in the Assam Valley receive more than 1,650 mm. (65 in.). This is sufficient for the cultivation of wet rice without irrigation. Furthermore, rain is certain every year, relieving the Assamese from the uncertainty of cultivation so familiar elsewhere in India.

Soil. The soil along the banks of the Brahmaputra varies from heavy clay to sand and gravel. Generally the heaviest clay is found in the depressions between levees, while the more elevated land consists of sediments of coarser texture. Almost all the land of the plains districts is of recent alluvial origin. In the Goalpara Duars the soil, for the most part, is light and gravelly. The higher land in Sibsagar, an elevated tract of land north of Tezpur, and the Bisnath plain in Darrang District are the remains of an older alluvium which has disappeared elsewhere.

The elevation of the land in relation to the water level of the adjacent rivers is, however, a more important factor with regard to the suitability of the land for agriculture than the texture of the soil. Thus the land under tea bushes is generally found on terraces a few feet above the local flood-water level. Lowlying land within the gardens is not so well drained and may be used for the cultivation of wet paddy. Wheat, maize and other dry rabi crops may be cultivated on areas that are not flooded. Double cropping is possible with irrigation.

Floods and Silting. The heavy rainfall on the slopes of the Himalayas and the Burma Ranges causes serious flood problems. At points of confluence along the Brahmaputra the water of the tributaries is dammed up by the huge water masses of the main river, resulting in floods on the neighbouring fields.

The heavy load of silt carried by the rivers of Assam results in frequent shifting of the river courses. Even these shifting river beds with bhils and marshy land may be used for agriculture if drained in the dry season.

The bed of the Brahmaputra has been raised significantly in Upper Assam in recent years due to silting. This can be seen from the following figures, giving averages for the low water levels at Dibrugarh: 1931-35, 323.70 feet; 1936-40, 321.74 feet; 1941-45, 320.93 feet; 1946-50, 323.80 feet; 1951-55, 331.80 feet. In August 1954 the maximum water level of the Brahmaputra was 343.00 feet, the highest water level recorded up to 1957.

Arable Land. Even though the authorities refuse to admit that arable waste land is available in the Assam Valley, immigration—but to a diminishing degree—has continued since 1951. New land is being taken up every year, and there still seems to be room for further expansion.

A study of the population density (Fig. 3) indicates that the largest tracts of uncultivated land are in Goalpara, Kamrup south of the Brahmaputra, Lakhimpur and Sibsagar, particularly in the subdivisions of North Lakhimpur and the Golaghat subdivision of Sibsagar. The latter subdivisions have attracted settlers only to a minor extent. North Lakhimpur has been open to settlers, but the land is much threatened by floods and is isolated with regard to communications. The land in Golaghat has provided little opportunity for settlers because of the large areas of reserved forests, and squatters have avoided this Sibsagar tract bordering the jungle for fear of robbery by Naga rebels.

Large areas of dry and flooded land are still found all over the plains, which, by river regulation, irrigation and with the cooperation of the farmers, may represent a valuable reserve of arable land.

CONCLUSION

In conclusion it may be claimed that there is room for a larger agricultural population on the plains along the Brahmaputra, because the intensity of agriculture and the productivity of the land can be increased, and because it is possible to extend the area of cultivated land.

Even if the area under forest is not reduced, paddy fields can be cultivated on the lowlying land within the forest reserves. With improved forest cultivation the State's need for forest products may be satisfied with a smaller area of forest land. If the hill areas can be utilized in planned forest production, the area of reserved forests on the plains might be reduced thus providing more land for agriculture. As the agricultural population increases, a conflict between the foresters and the settlers seems inevitable. To solve this problem a thorough knowledge of the productivity of the forests and an accepted estimate of the nation's present and future needs of forest products is required.

It is unlikely that the land under tea will be extended. Indian tea production was reduced several times between the wars, and although production has increased every year since the Second World War, no new land has been taken into use. Also, new tea producers in East Africa compete favourably with Indian tea on the overseas markets, although it is true that the home consumption of tea is increasing with improved living standards.

It may be assumed that in time the tea gardens will no longer need their forests for fuel, because coal and oil or electric power will be easier to obtain. Also tea estates do not approve of their labourers having their own paddy fields because the plucking season, when the labourers are needed every day, coincides with the time when the most intensive work is needed in the paddy fields. This means that eventually the main part of the excess land owned by the tea gardens could be released for settlement.

The real waste land probably represents the largest area of potential arable land. As the tracts best suited for agriculture are taken up by settlers, better knowledge about the land situation will be required of the land settlement authorities. Organizational skill and goodwill must be assured if the authorities are to lead the land-hungry people to the unoccupied plots suitable for farmland. The challenge represented by the tracts which, with the traditional Bengali methods of farming, are regarded as uncultivable can be met by means of river control, and capital investments in improved agricultural techniques. Progress will demand the skill both of the engineer and the agronomist.

This article has discussed the remarkable growth of Assam's population by immigration, the land use and the possibility of extending the area of cultivated land. The question now arises: what is the maximum population that can be supported by the land in the Assam Valley? Such a question can be answered only if an acceptable standard of living for the agricultural population is defined.

The national income of Assam is low, and it is generally accepted that the Assamese farmers are as poor as the Indian farmers. Special attention may be paid to the fact that the indigenous Assamese peasants are worse off than the immigrant farmers, indicating that a low standard of living in the countryside is not necessarily a result of pressure on the land, but may be a result of low productivity caused by the existing social system and the lack of incentive on the part of the people.

The 'grow more food campaigns', which have been introduced under the Five Year Plans, aim at improving the standard of living of the people. In Assam these campaigns have been directed more at increasing the productivity than at making an effort to put all the available land under the plough.

Immigration into the Assam Valley has not brought relief to the population problems of the districts from which the immigrants have come. But if the immigration continues, it is obvious that the Assam Valley will soon be in exactly the same position as the over crowded countryside of the rest of India. The Assamese authorities are therefore discouraging further immigration. The industrial possibilities of Assam are very limited, and in the near future there will be a growing demand for new land by the indigenous Assamese population which is increasing through natural growth.

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